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(54) **LOOK UP TABLE (LUT) BASED CHIPLET TO CHIPLET SECURE COMMUNICATION**

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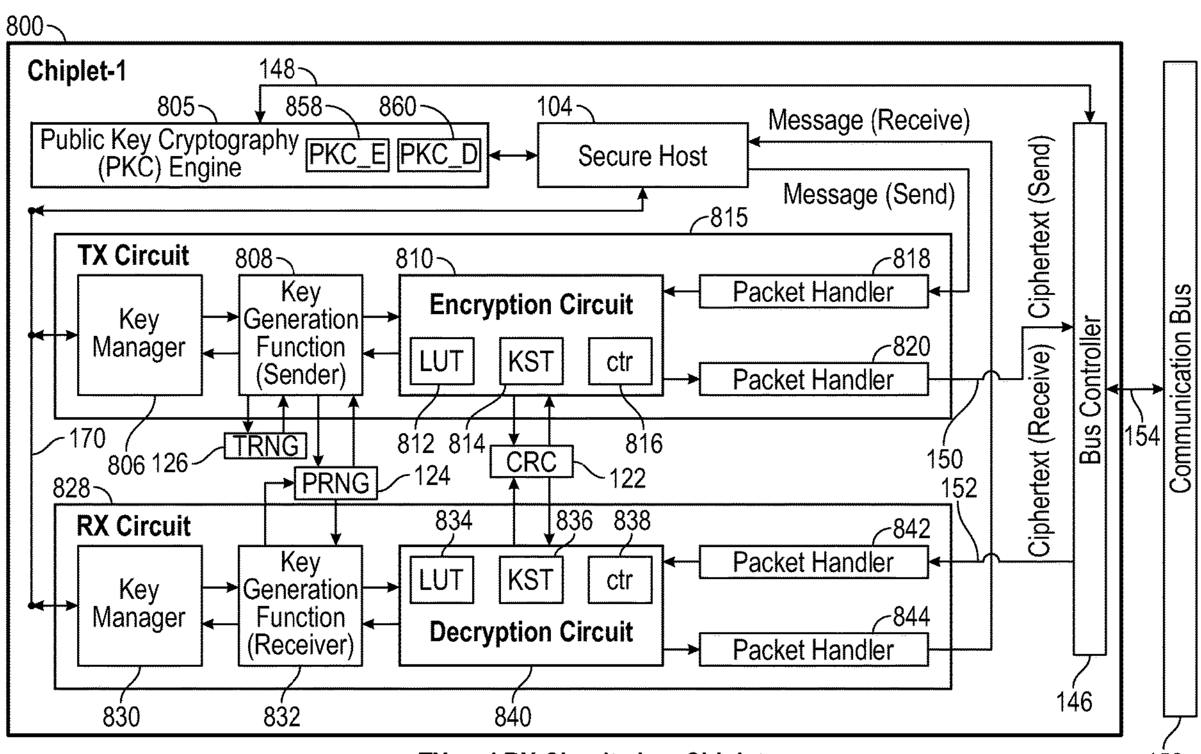
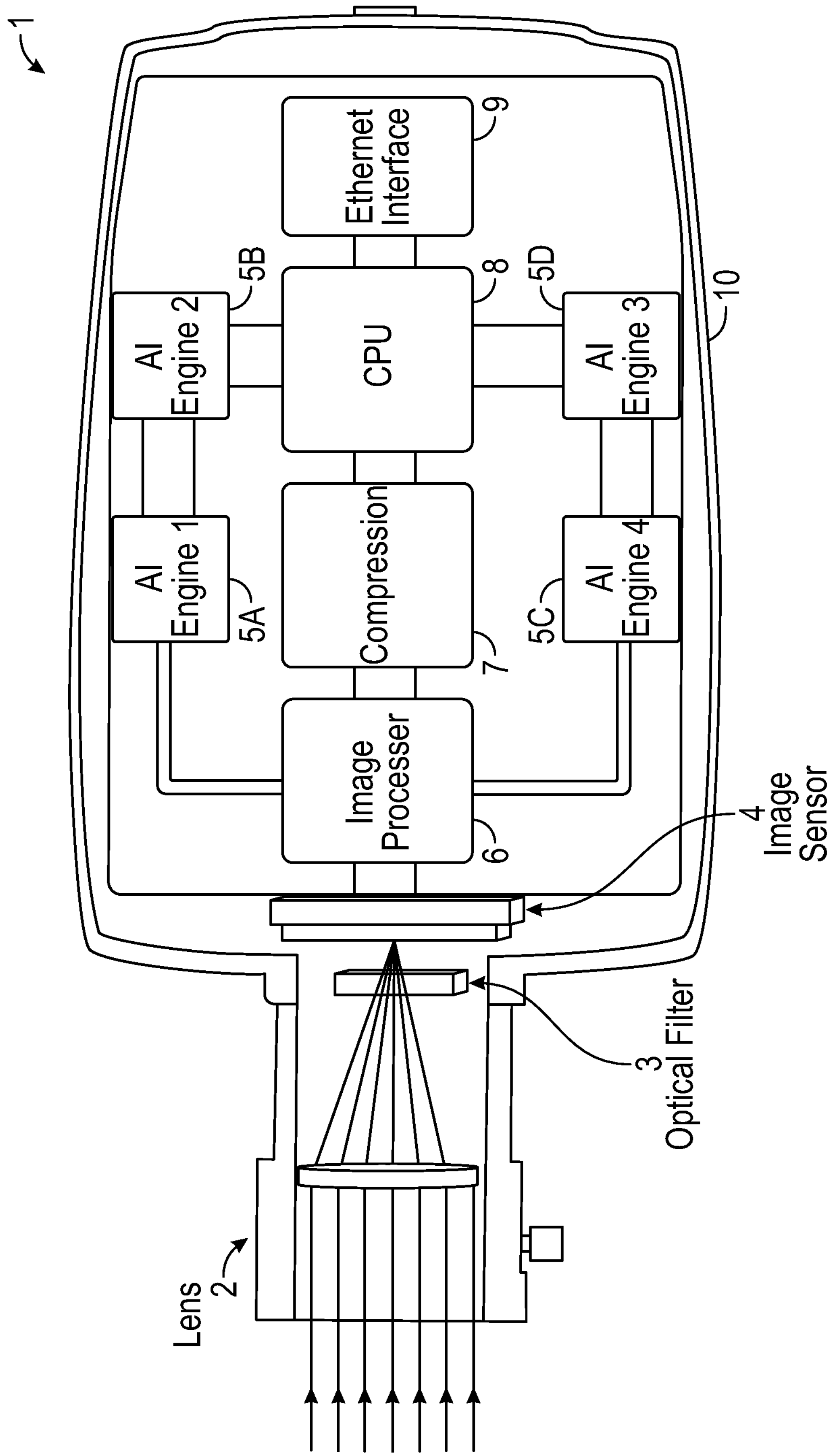
CPC ***H04L 9/0618*** (2013.01); ***H04L 9/14*** (2013.01)

(57) **ABSTRACT**

A cryptographic method includes (1) with the first chiplet, parsing a message into one or more message blocks (2) dynamically generating a first target value that is associated with a first key (3) dynamically generating a second target value that is associated with a second key (4) encrypting at least one message block of the at least one or more message blocks to generate some ciphertext, the encryption being performed with at least one operation that includes at least one XOR operation, the at least one XOR operation performed at least in part with the first target value and with at least the second target value, the first target value and the second target value being accessed via the first and second keys, respectively; and (5) with at least one processing device associated with the first chiplet, transmitting the some ciphertext to a second chiplet.



TX and RX Circuits in a Chiplet.



Resource - Constrained Device
(Smart Camera)
FIG. 1

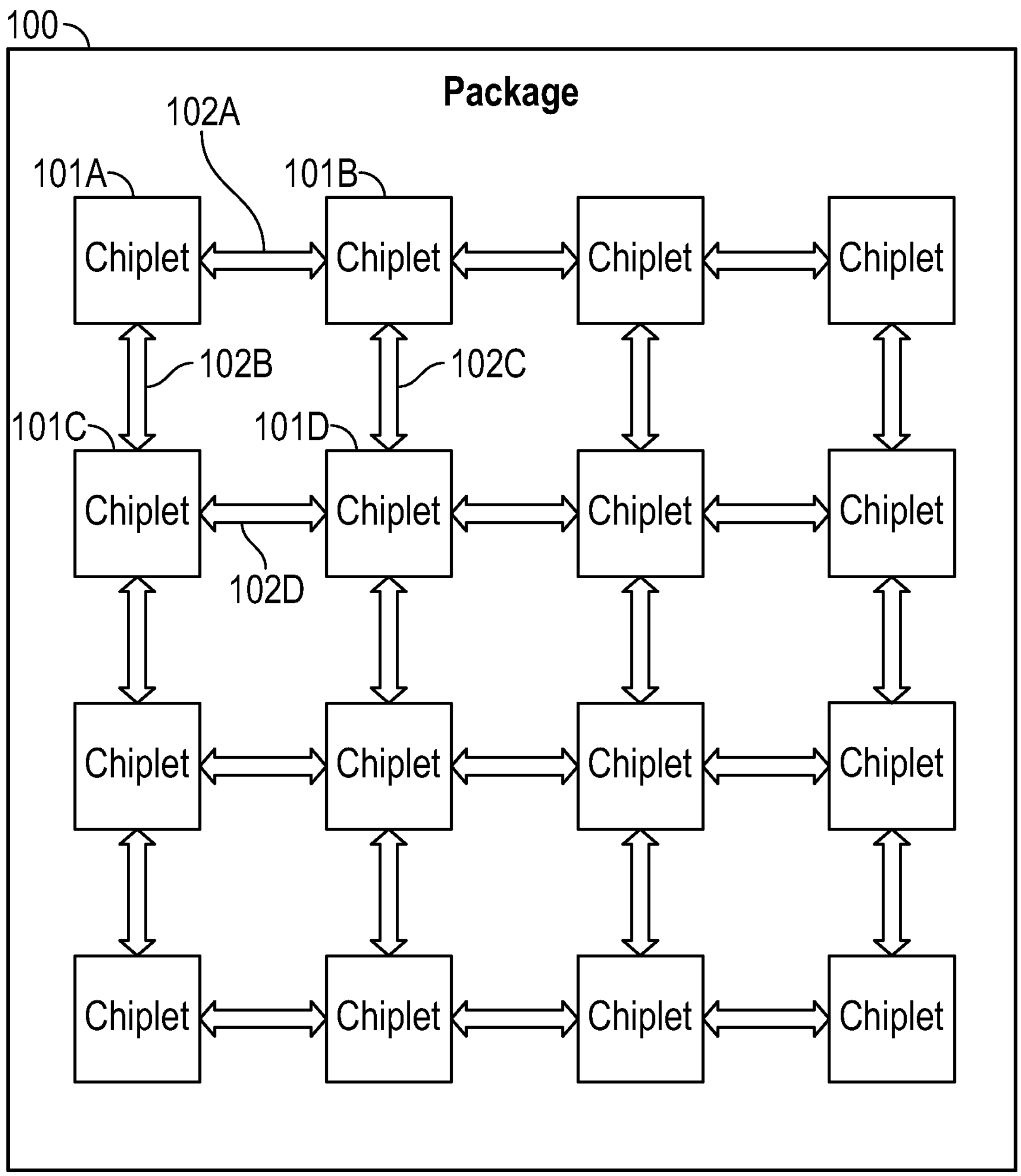

100
Package
102A
101A
101B
Chiplet
Chiplet
Chiplet
Chiplet
102B
102C
101C
101D
Chiplet
Chiplet
Chiplet
Chiplet
102D
Chiplet
Chiplet
Chiplet
Chiplet
Chiplet
Chiplet
Chiplet
Chiplet

FIG. 2

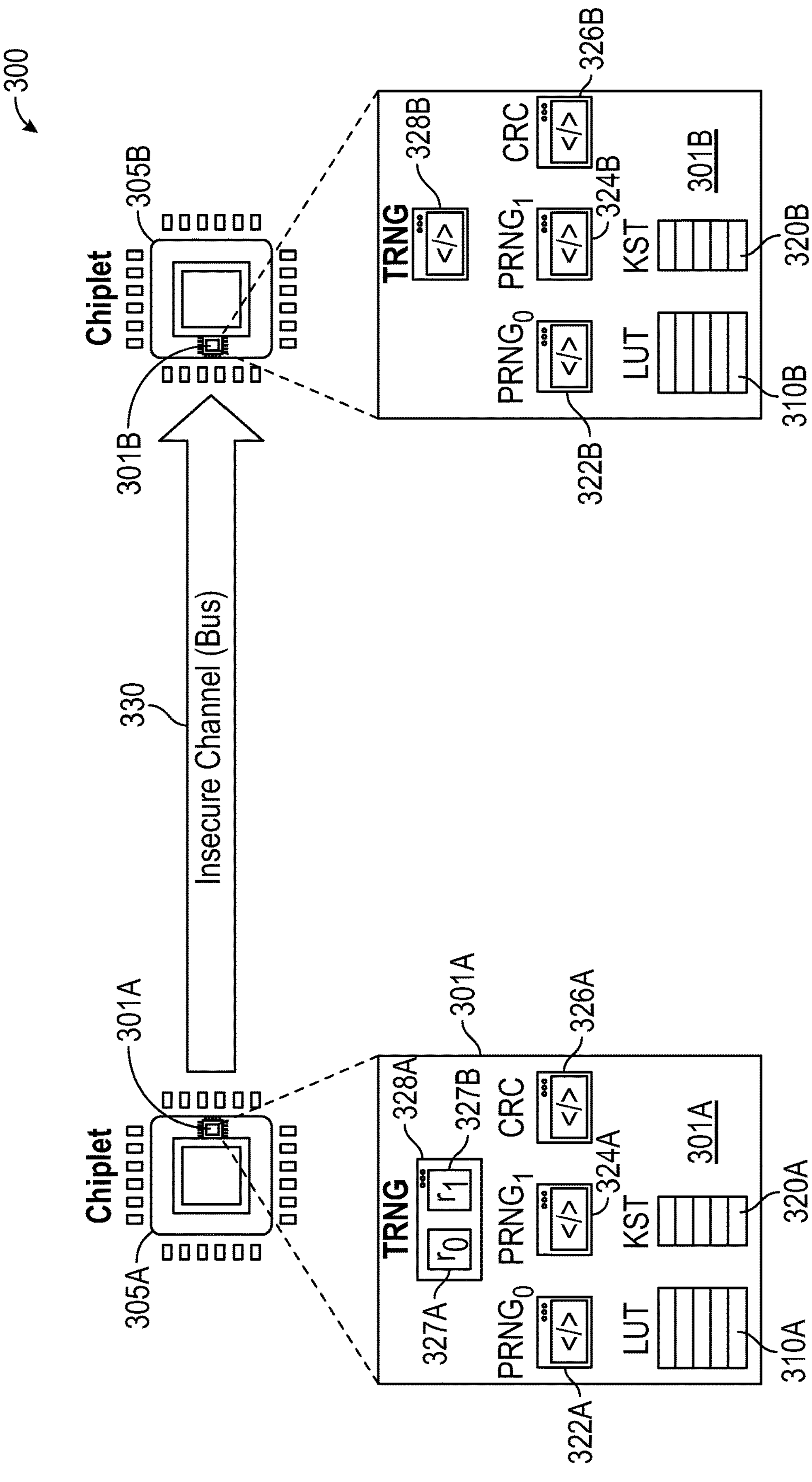

300
Chiplet
305B
301B
Chiplet
305A
301A
330
Insecure Channel (Bus)
TRNG
328B
CRC
326B
PRNG$_1$
324B
PRNG$_0$
322B
LUT
310B
KST
320B
301B
TRNG
r_0
r_1
327A
327B
328A
CRC
326A
PRNG$_1$
324A
PRNG$_0$
322A
LUT
310A
KST
320A
301A

FIG. 3

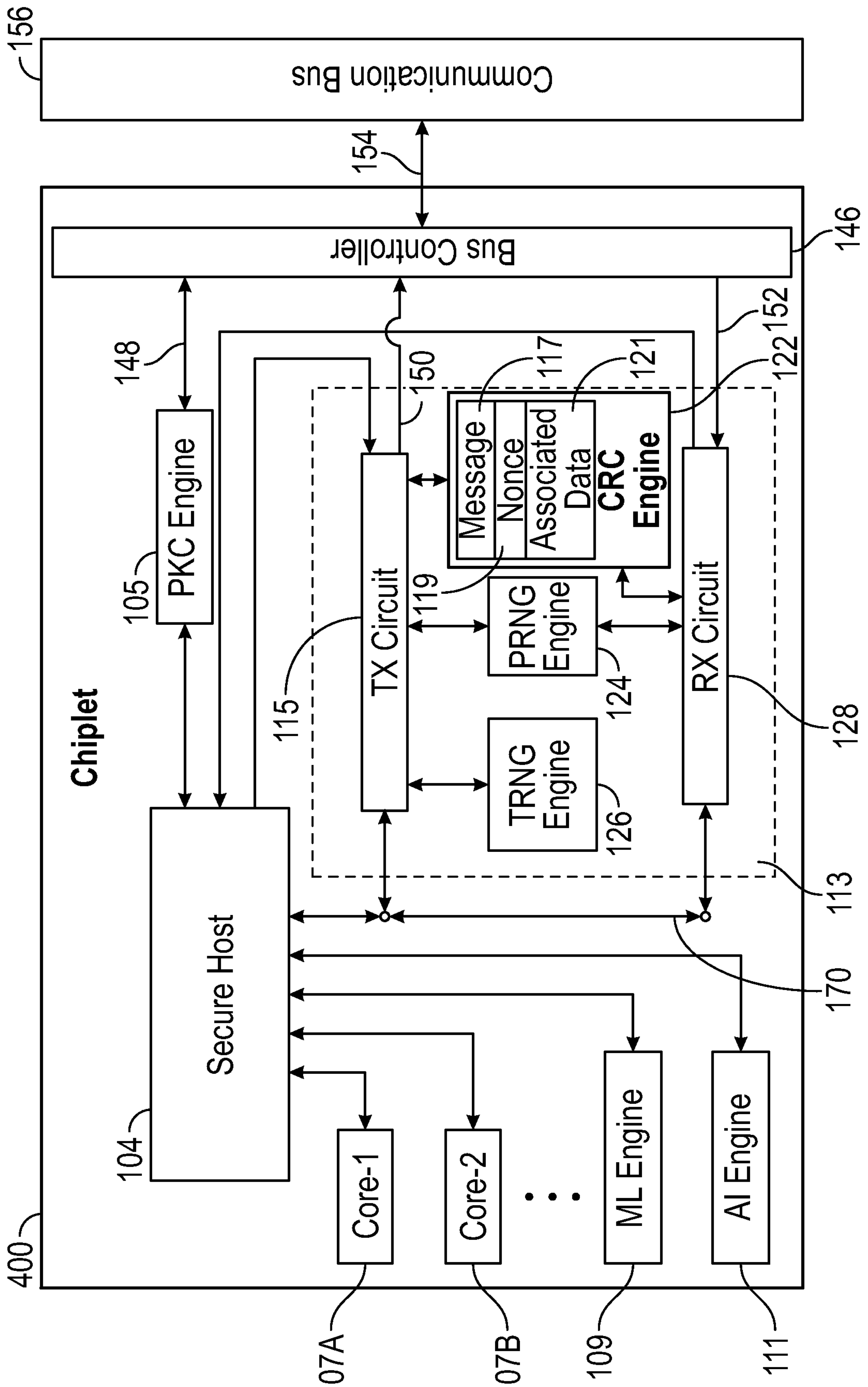

156
Communication Bus
154
400
Chiplet
146
Bus Controller
148
150
152
117
121
122
PKC Engine
105
Secure Host
104
TX Circuit
115
119
Message
Nonce
Associated Data
CRC Engine
PRNG Engine
124
TRNG Engine
126
RX Circuit
128
113
170
Core-1
Core-2
ML Engine
AI Engine
107A
107B
109
111

FIG. 4

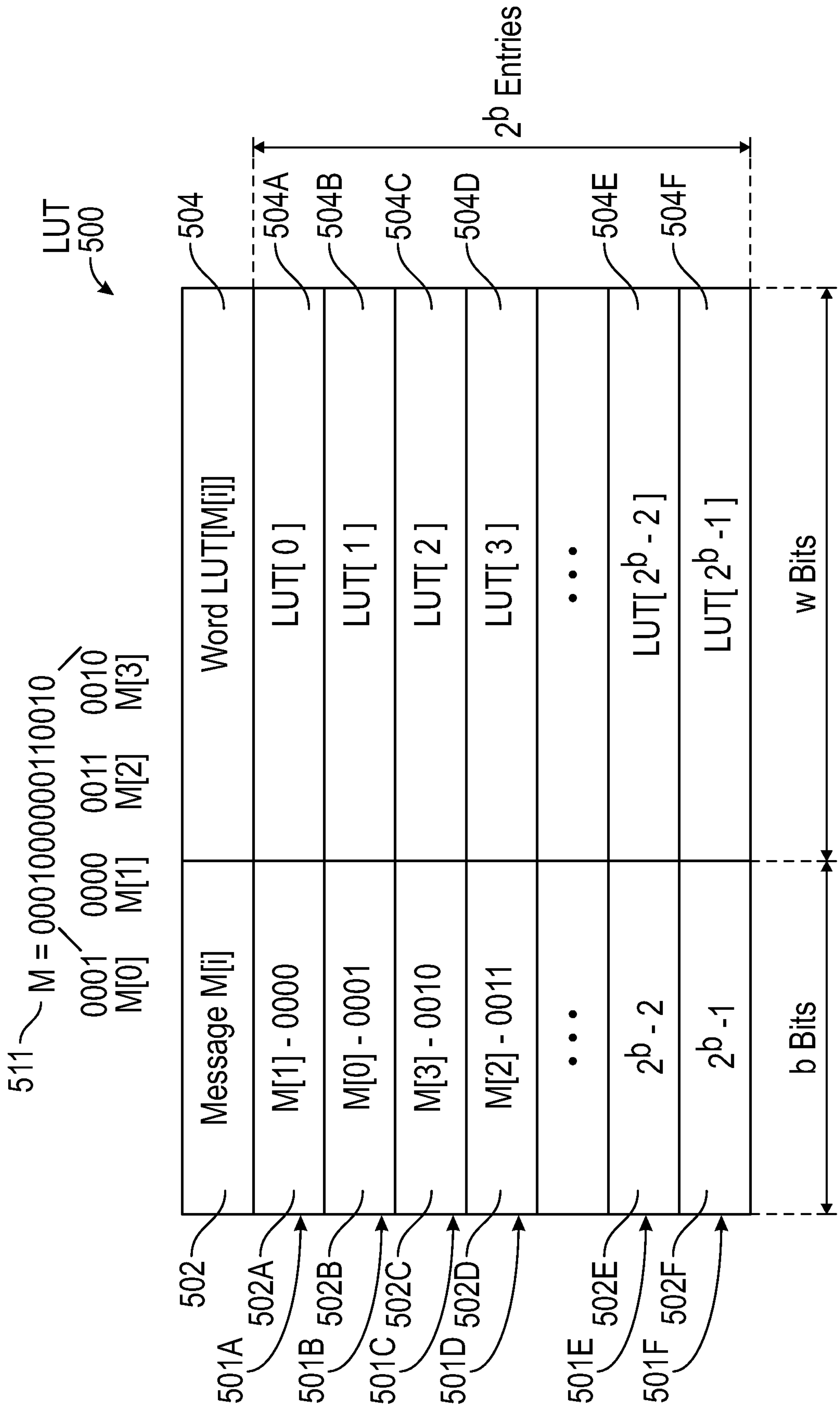

LUT
500
511
M = 0001000000110010
0001 M[0]
0000 M[1]
0011 M[2]
0010 M[3]
Message M[i]
Word LUT[M[i]]
M[1] - 0000
LUT[0]
M[0] - 0001
LUT[1]
M[3] - 0010
LUT[2]
M[2] - 0011
LUT[3]
• • •
• • •
2^b - 2
LUT[2^b - 2]
2^b -1
LUT[2^b -1]
b Bits
w Bits
2^b Entries
502
502A
502B
502C
502D
502E
502F
501A
501B
501C
501D
501E
501F
504
504A
504B
504C
504D
504E
504F

FIG. 5

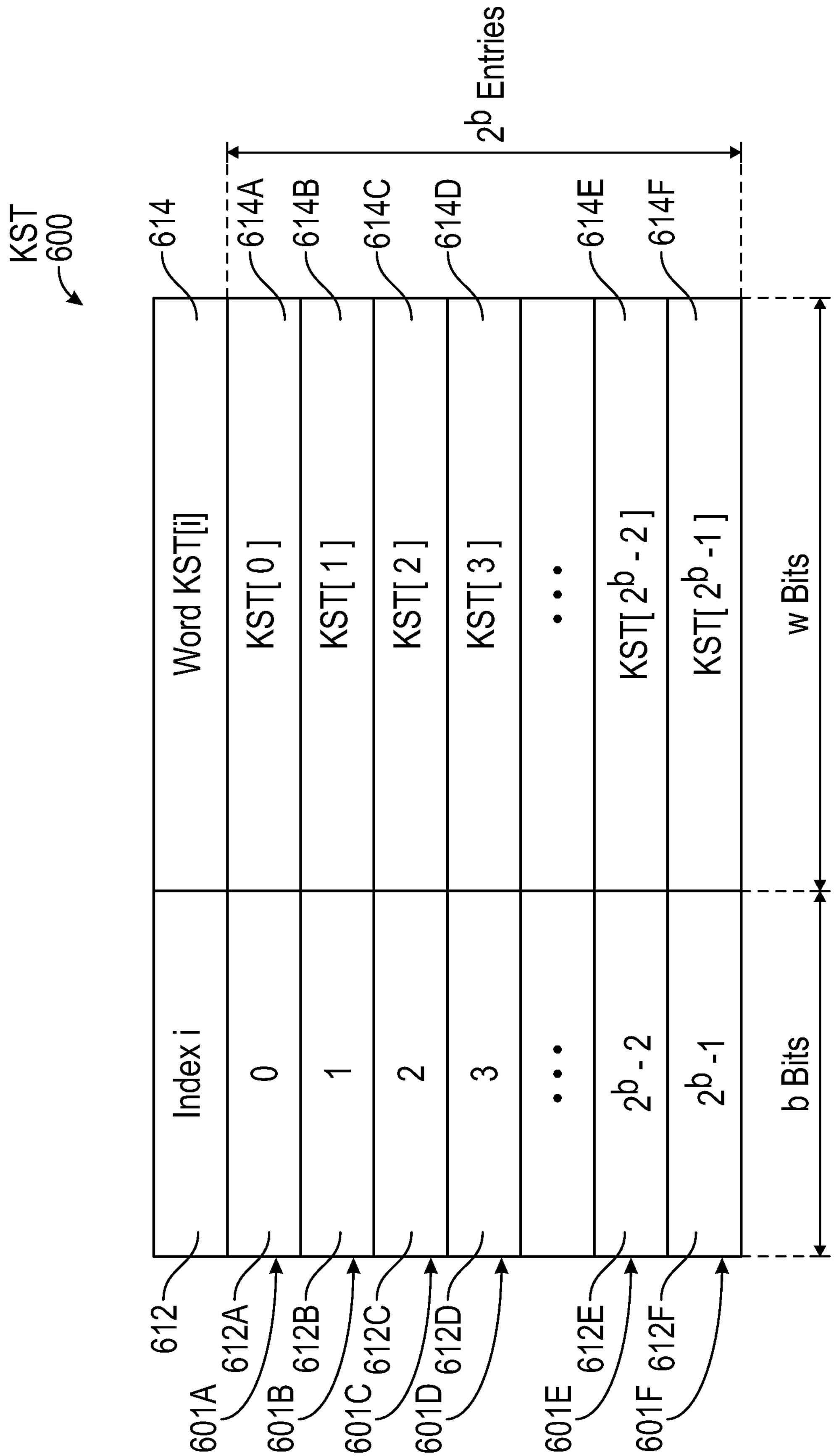

KST
600
2b Entries
614
614A
614B
614C
614D
614E
614F
Word KST[i]
KST[0]
KST[1]
KST[2]
KST[3]
KST[2b - 2]
KST[2b -1]
w Bits
Index i
0
1
2
3
2b - 2
2b -1
b Bits
612
612A
612B
612C
612D
612E
612F
601A
601B
601C
601D
601E
601F

FIG. 6

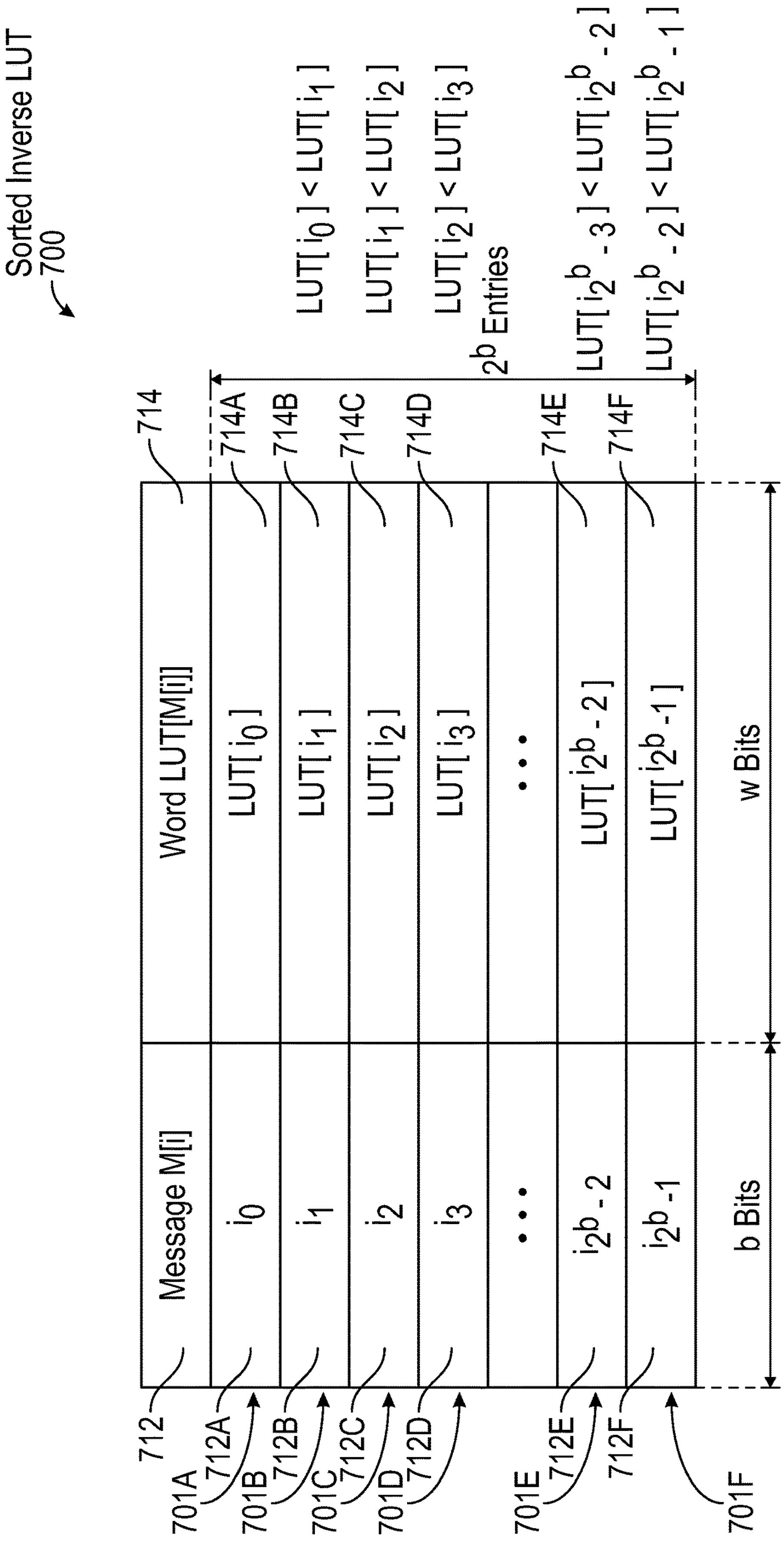
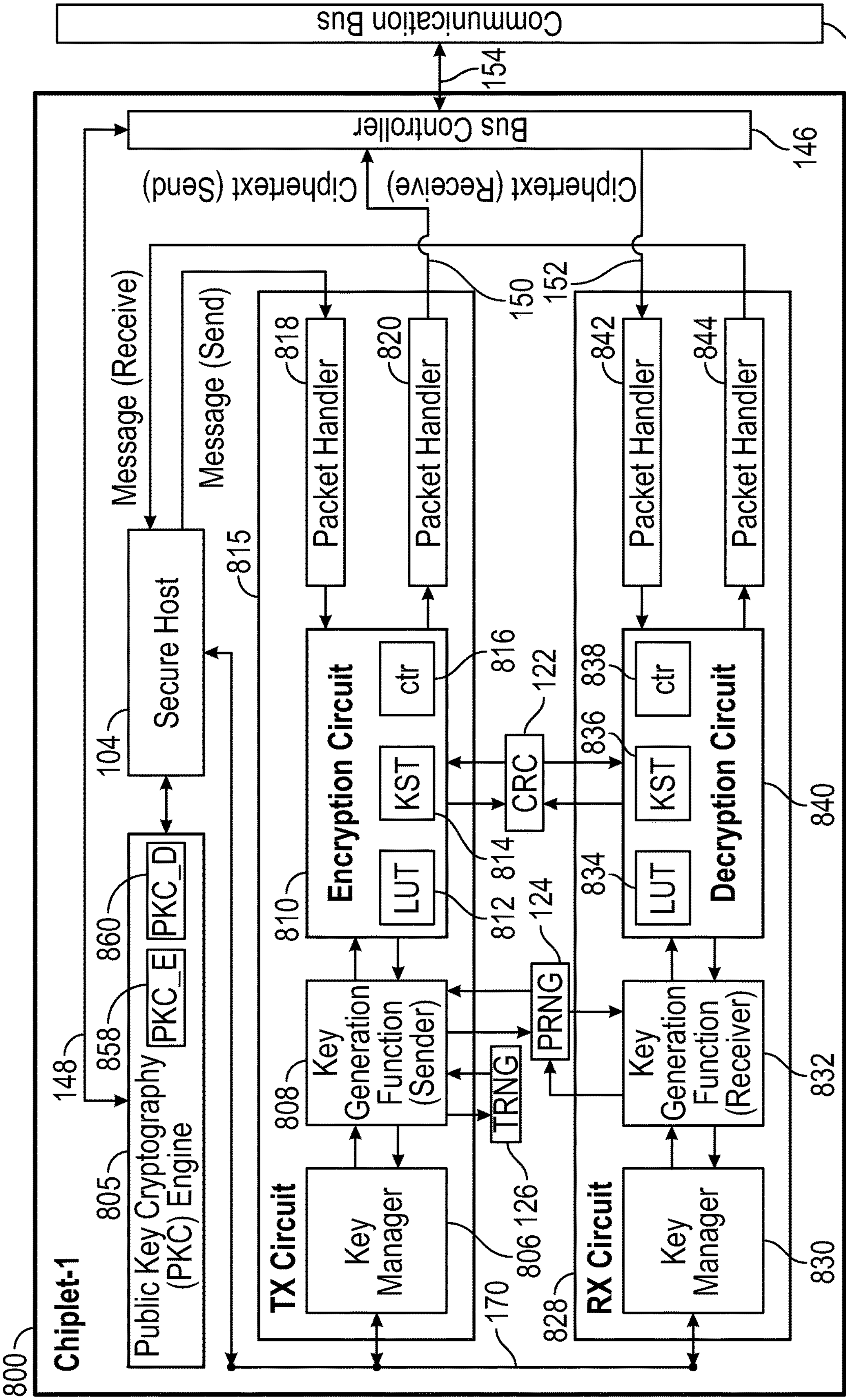
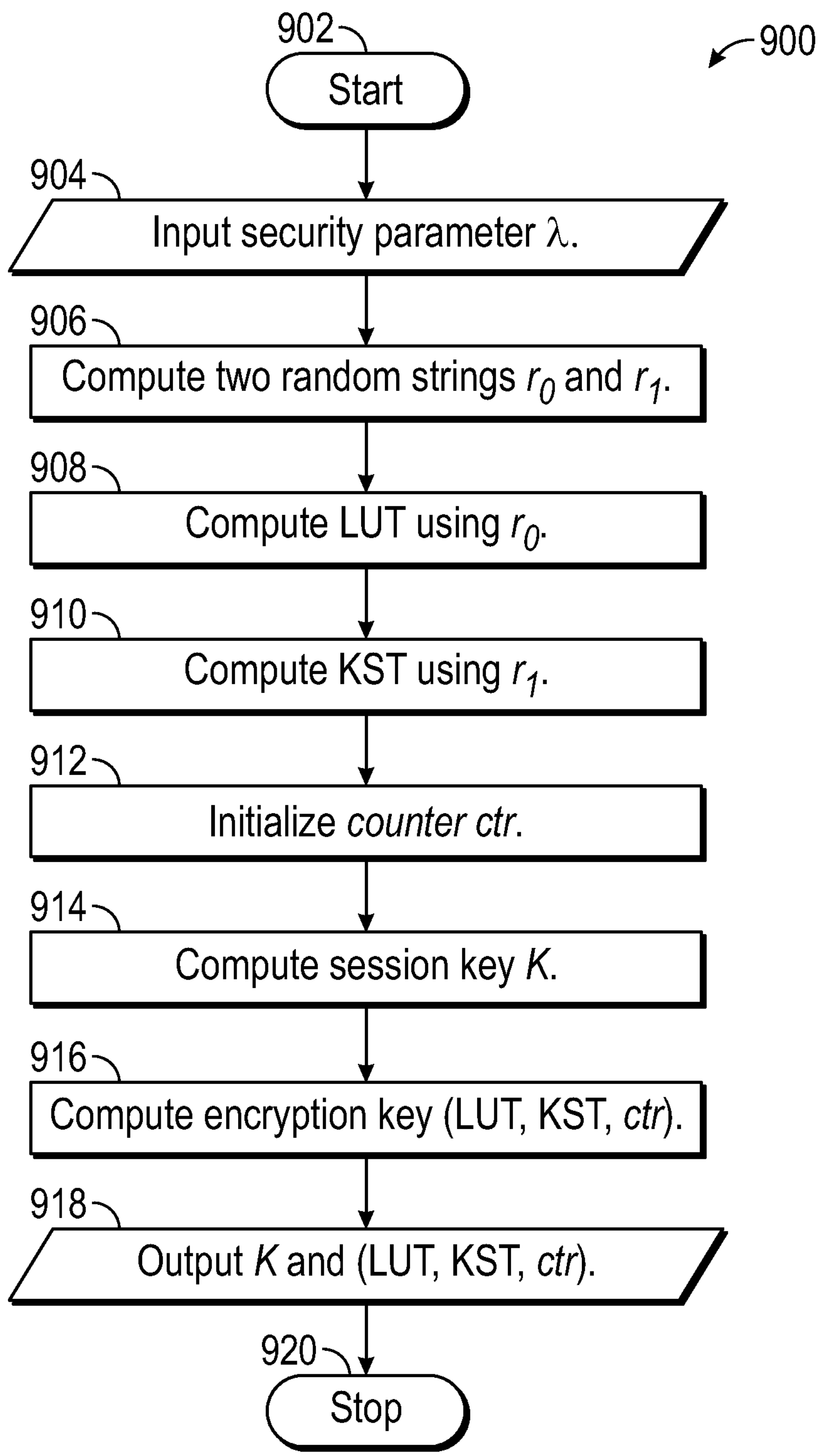

Sorted Inverse LUT
700
712
714
Message M[i]
Word LUT[M[i]]
701A
712A
714A
i_0
LUT[i_0]
LUT[i_0] < LUT[i_1]
701B
712B
714B
i_1
LUT[i_1]
LUT[i_1] < LUT[i_2]
701C
712C
714C
i_2
LUT[i_2]
LUT[i_2] < LUT[i_3]
701D
712D
714D
i_3
LUT[i_3]
2^b Entries
701E
712E
714E
i_{2^b} - 2
LUT[i_{2^b} - 2]
LUT[i_{2^b} - 3] < LUT[i_{2^b} - 2]
712F
714F
i_{2^b} -1
LUT[i_{2^b} -1]
LUT[i_{2^b} - 2] < LUT[i_{2^b} - 1]
701F
b Bits
w Bits

FIG. 7



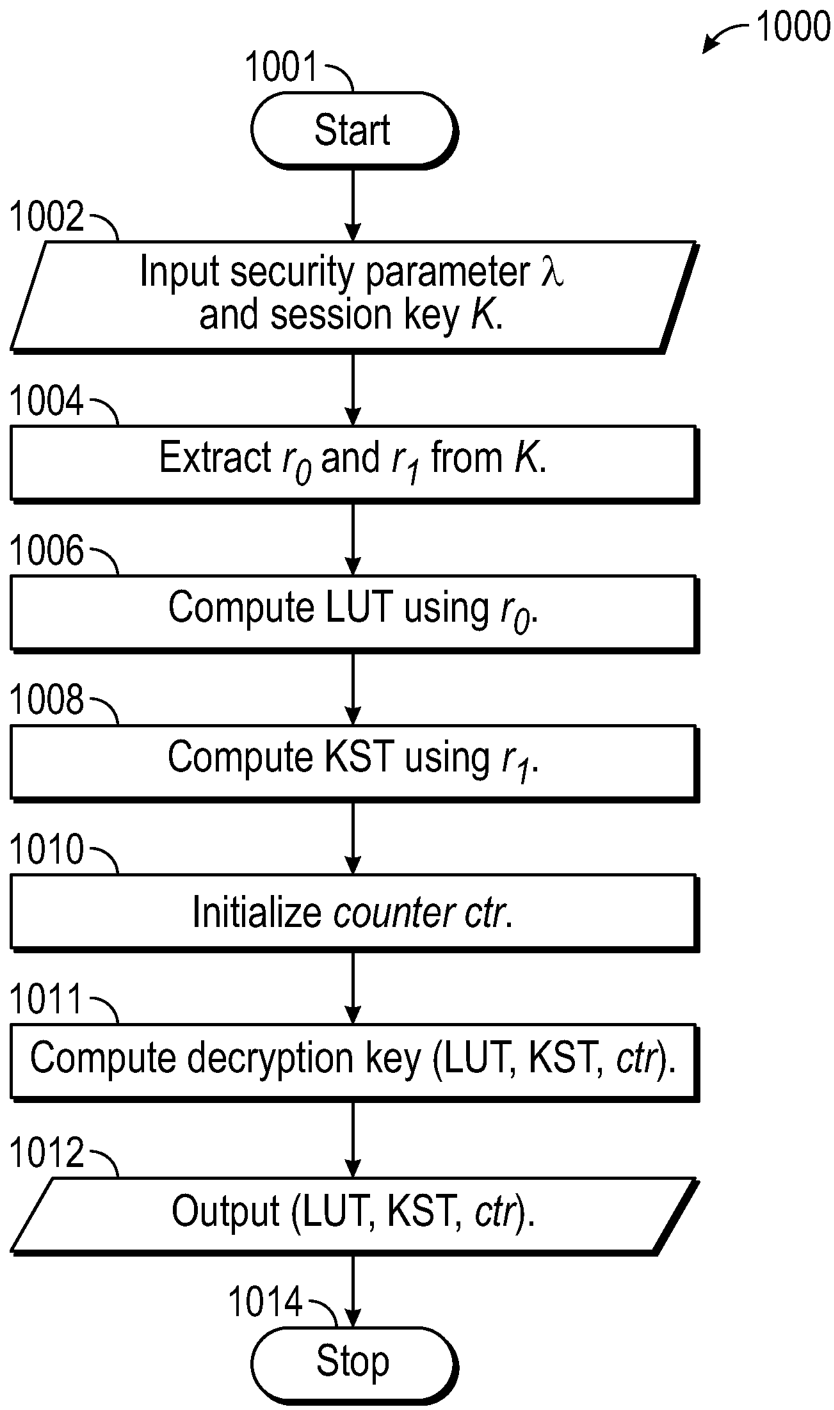
TX and RX Circuits in a Chiplet.

FIG. 8



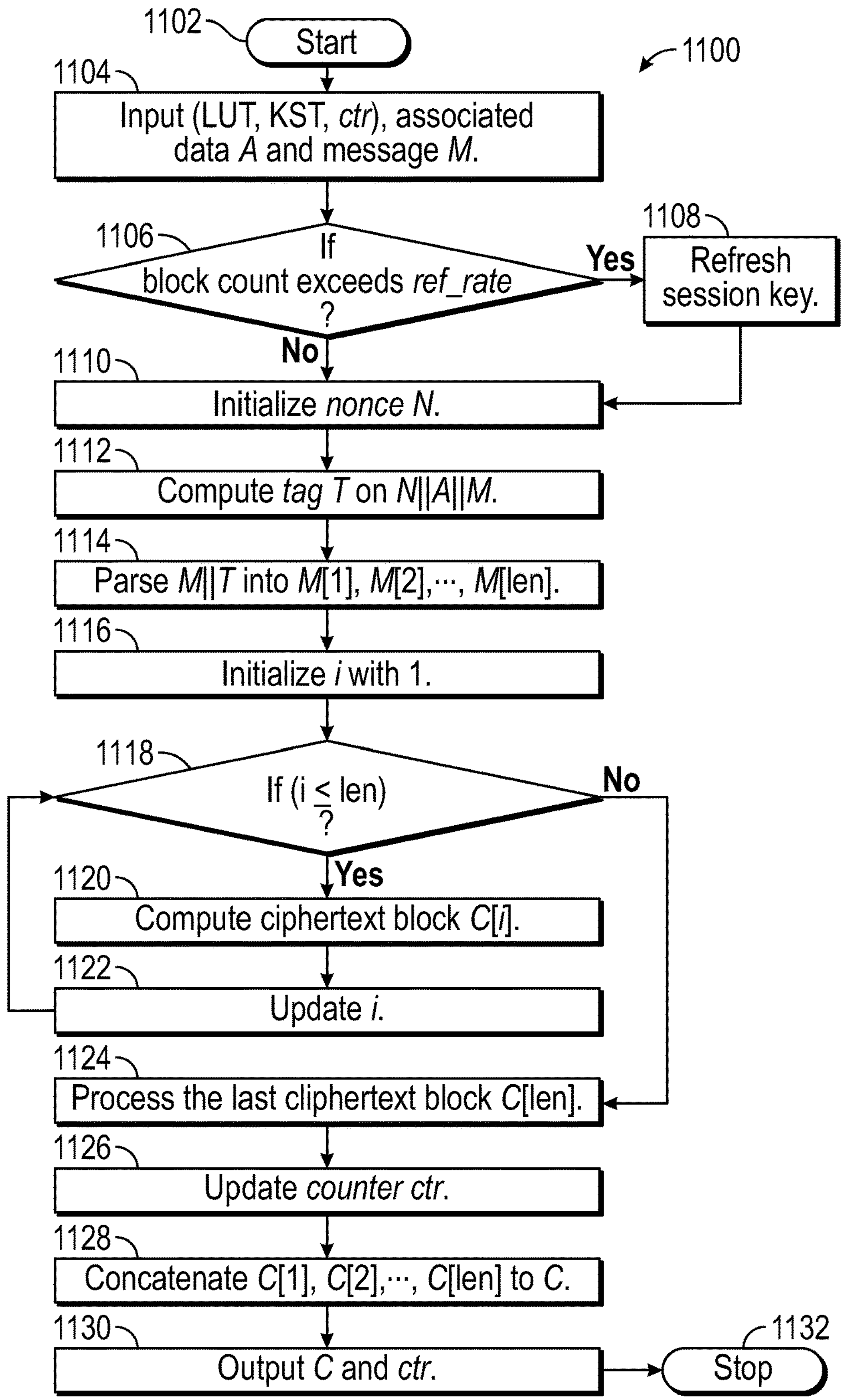
Flowchart-Key Generation Function (Sender).

FIG. 9



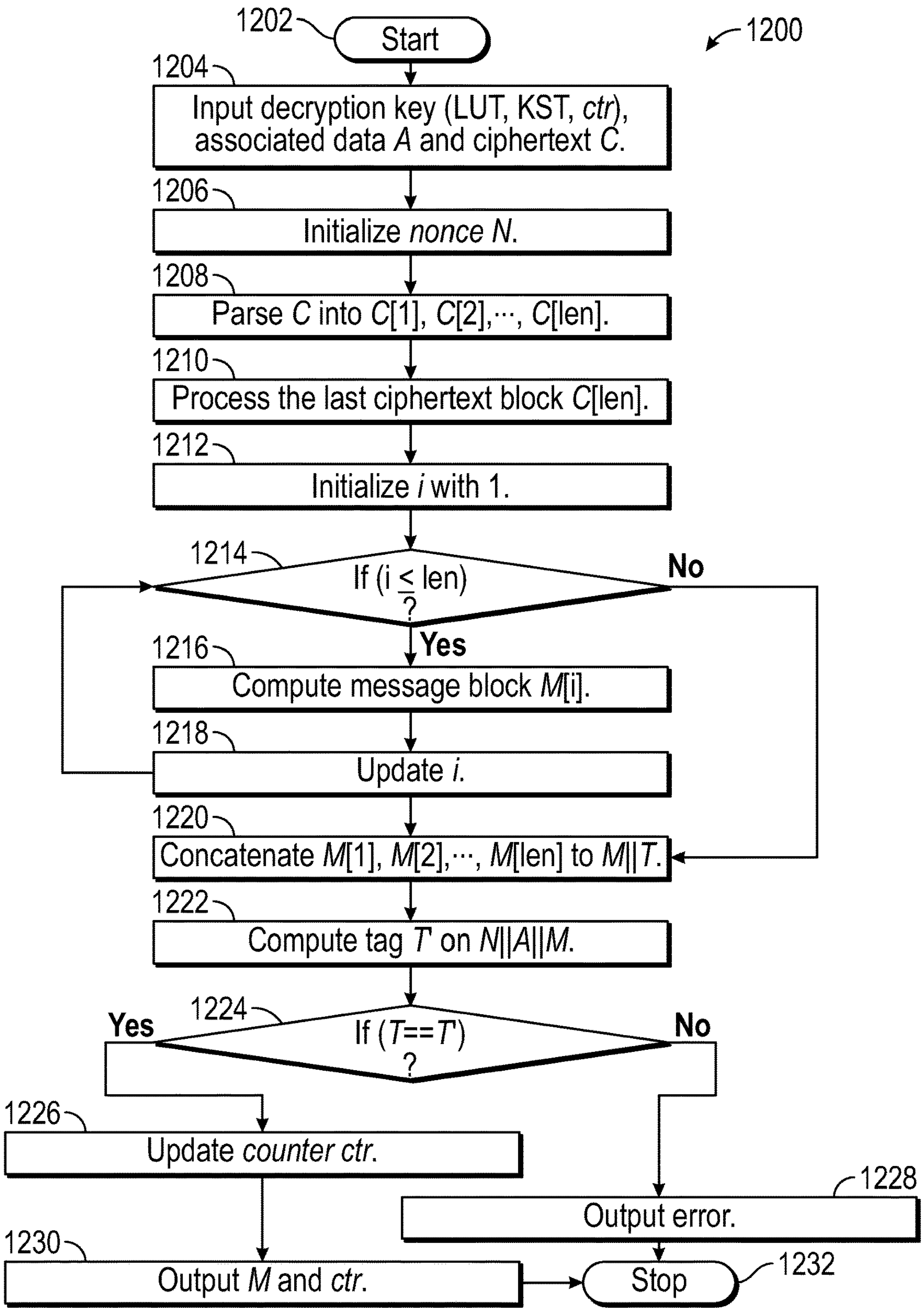
Flowchart-Key Generation Function (Receiver).

FIG. 10



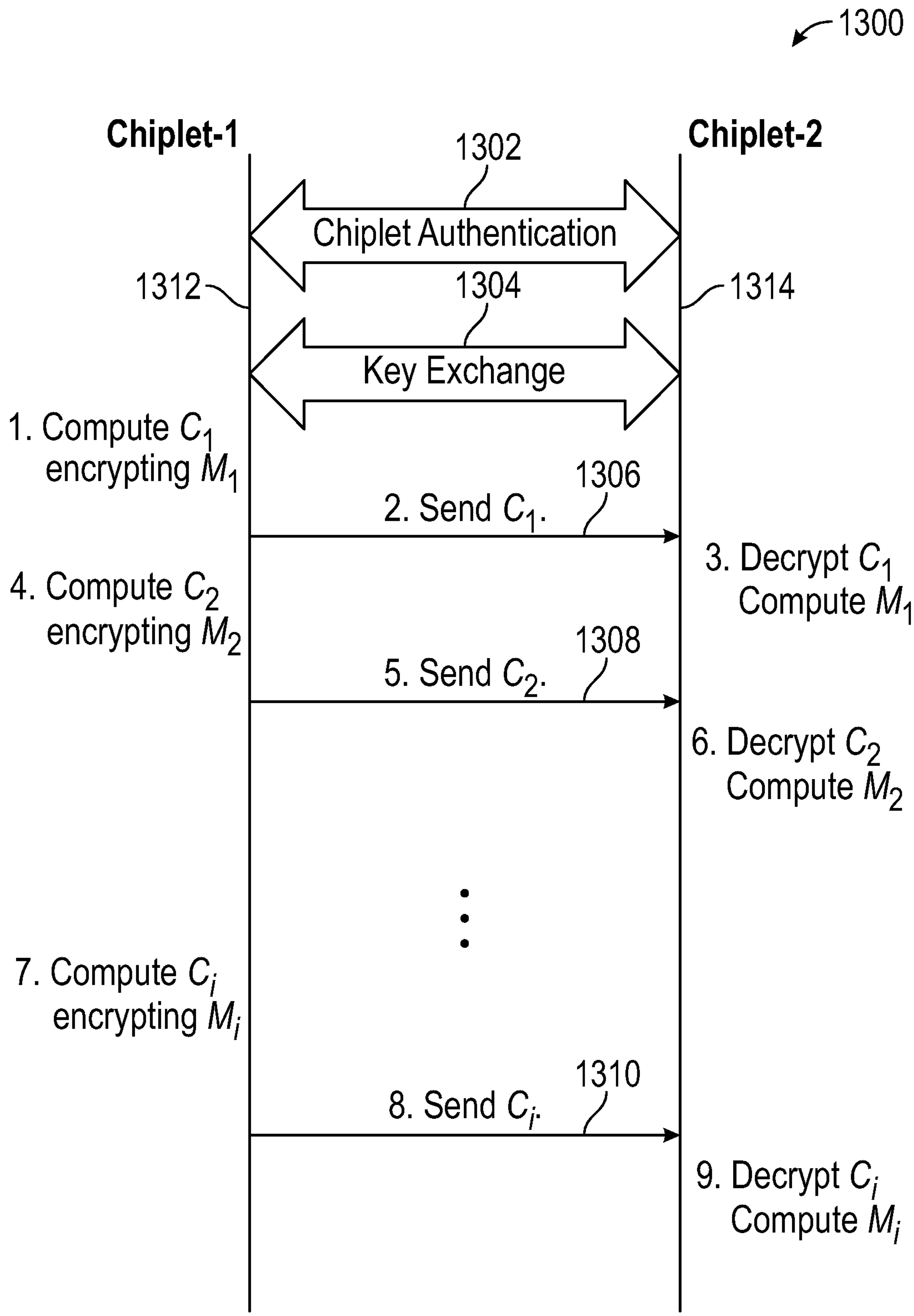
Flowchart - Encryption Function.

FIG. 11



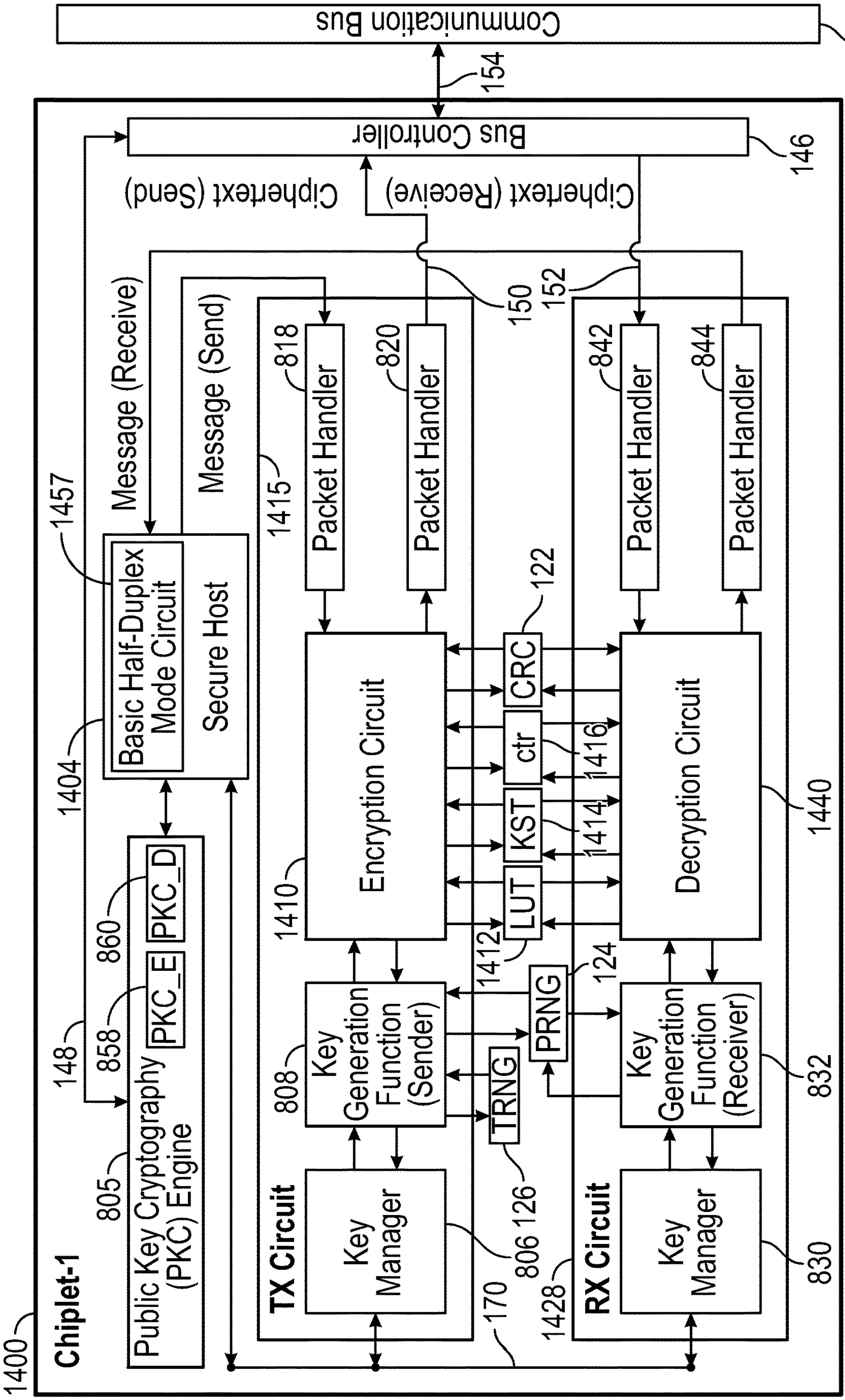
Flowchart - Decryption Function.

FIG. 12



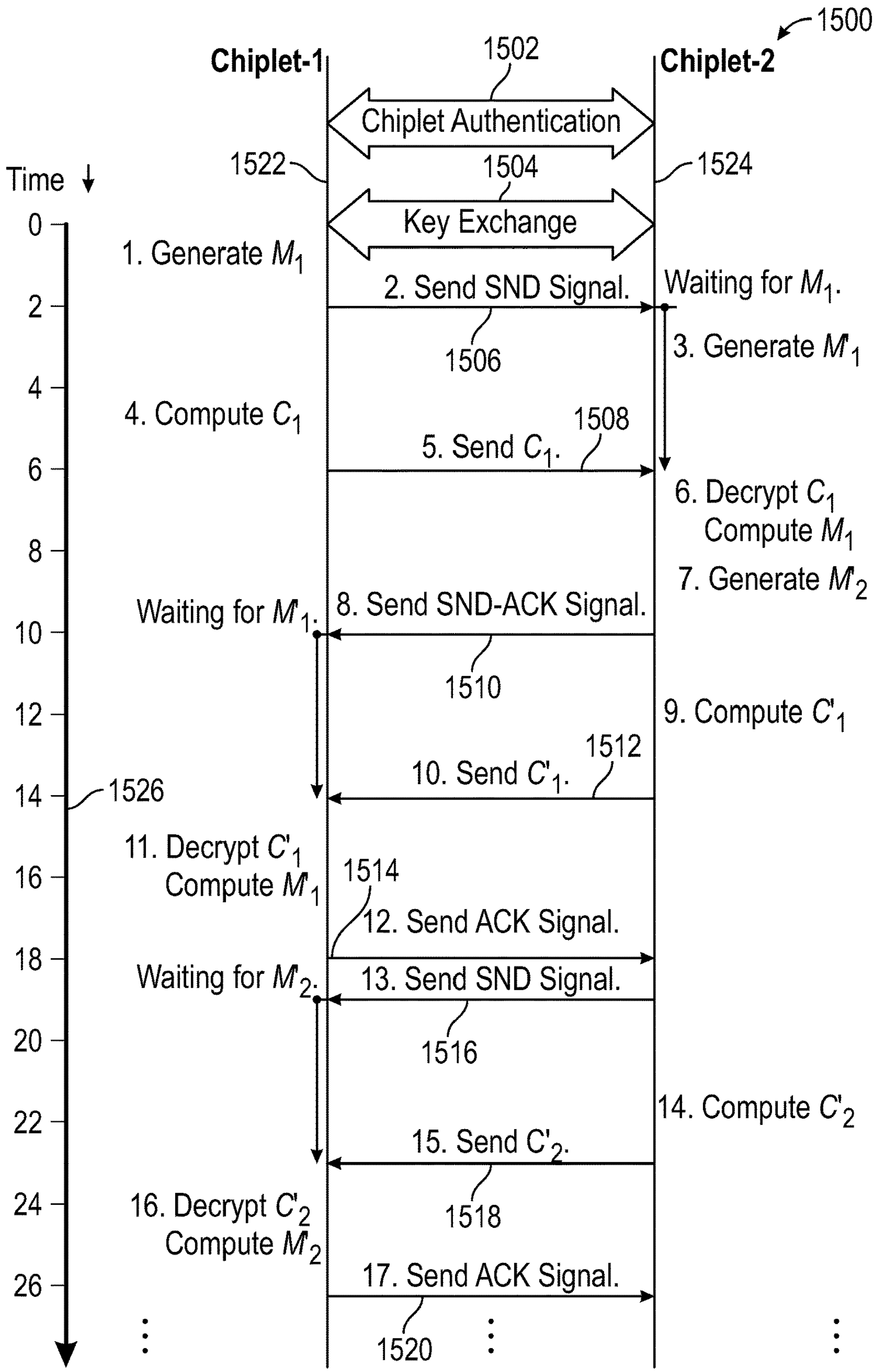
Multiple Communications M_1, M_2, ⋯, M_i Within One Session.

FIG. 13

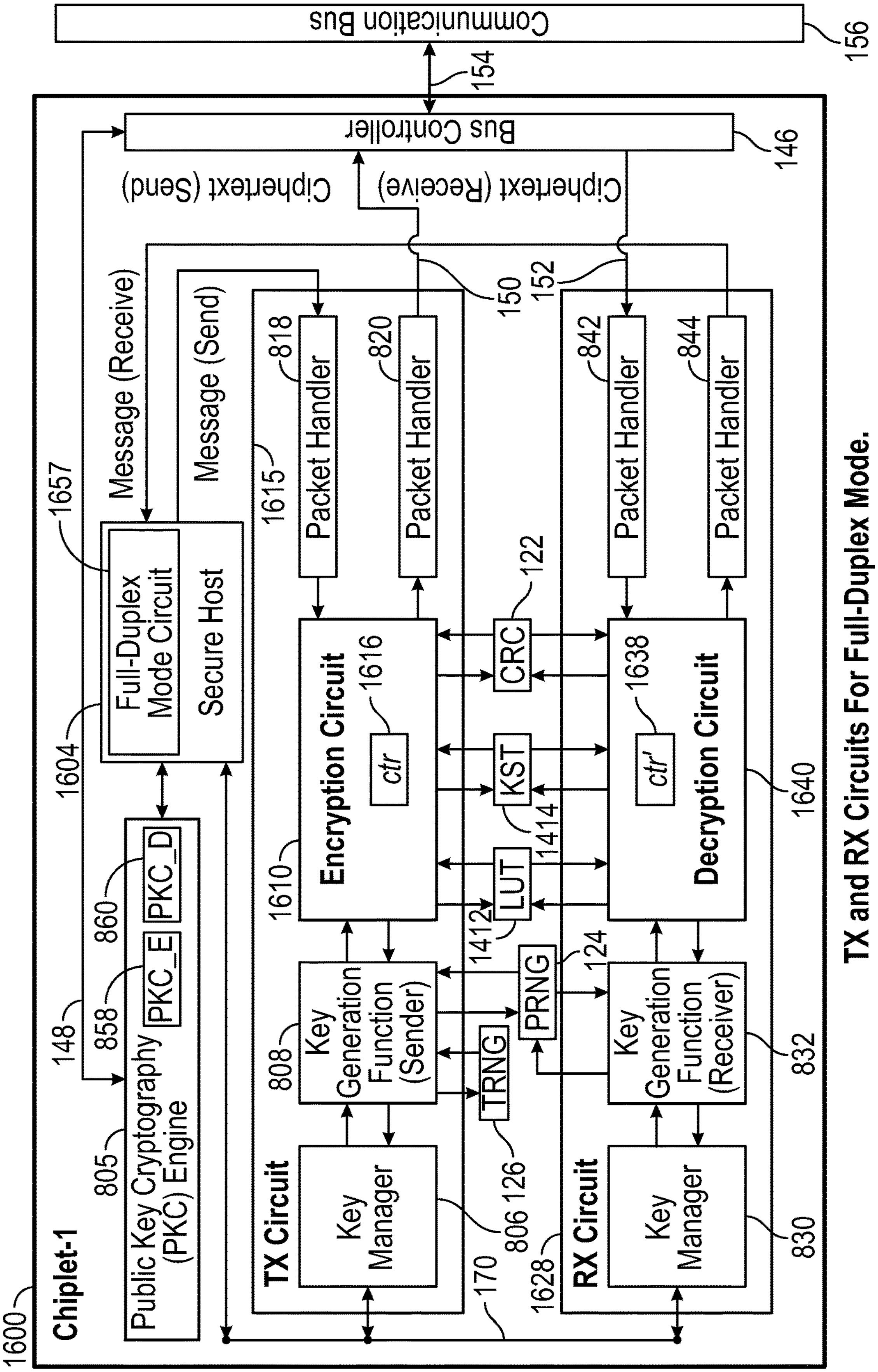


TX and RX Circuits For Basic Half-Duplex Mode.

FIG. 14

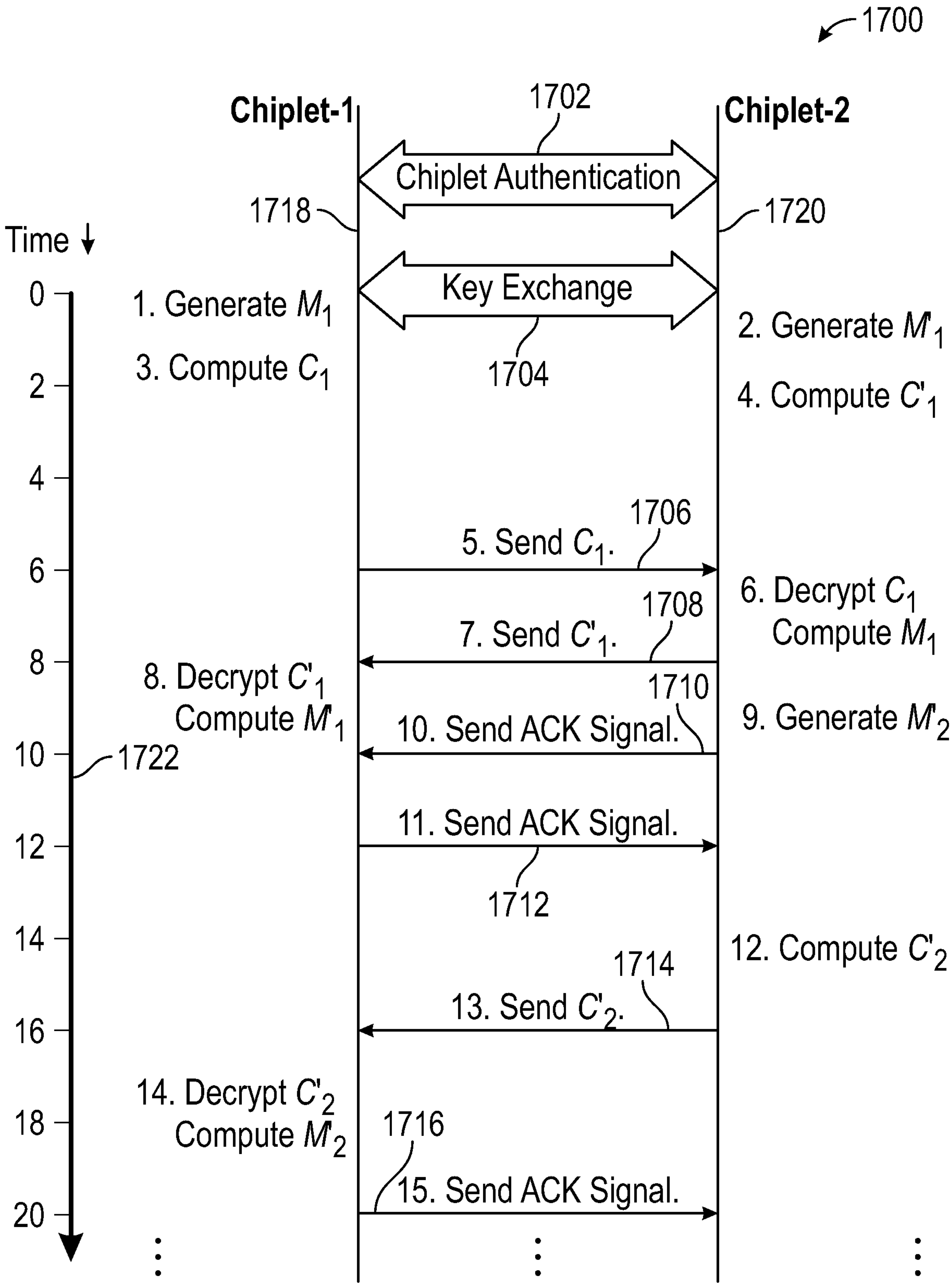


Basic Half-Duplex Mode of Operation.
FIG. 15



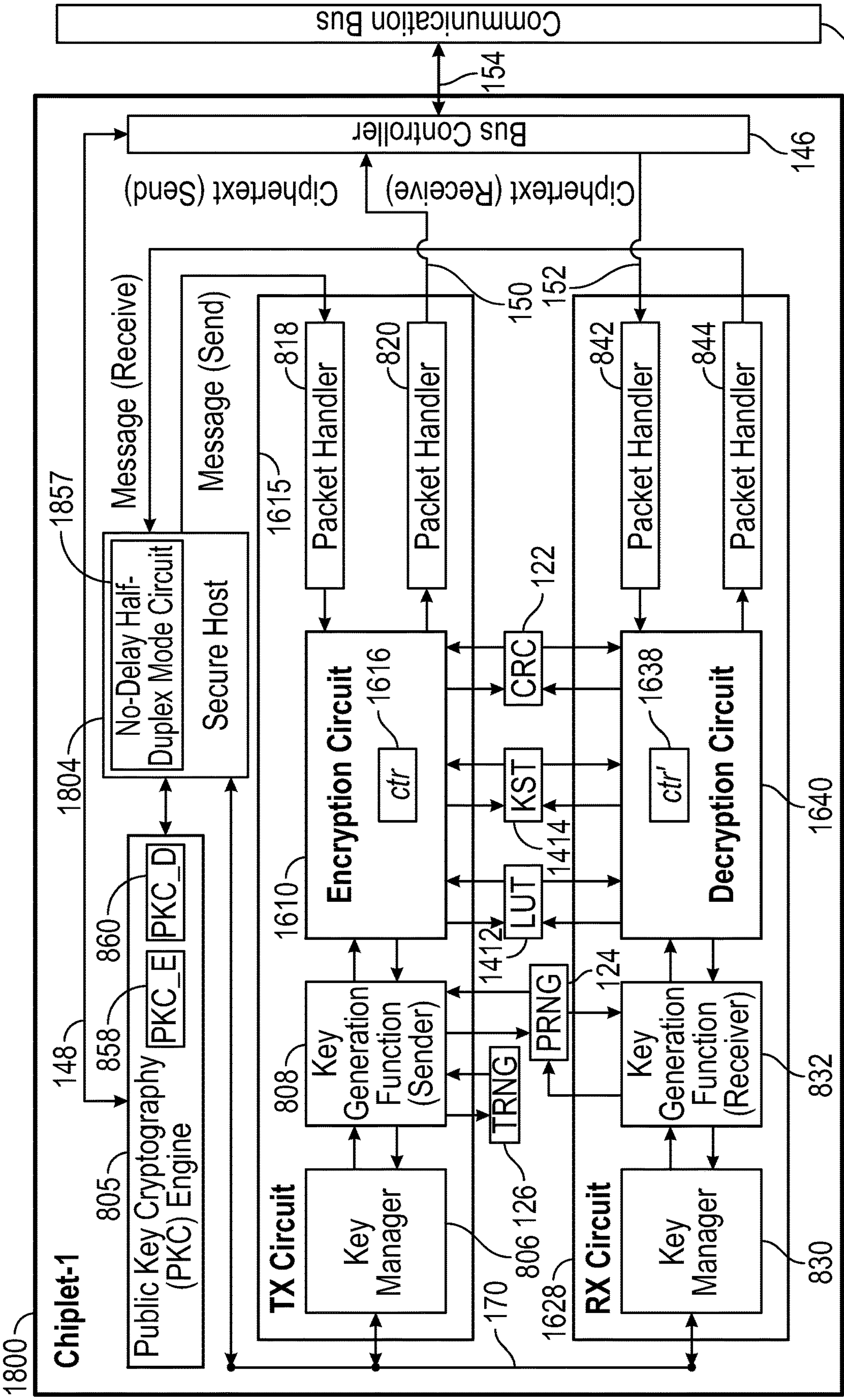
TX and RX Circuits For Full-Duplex Mode.

FIG. 16



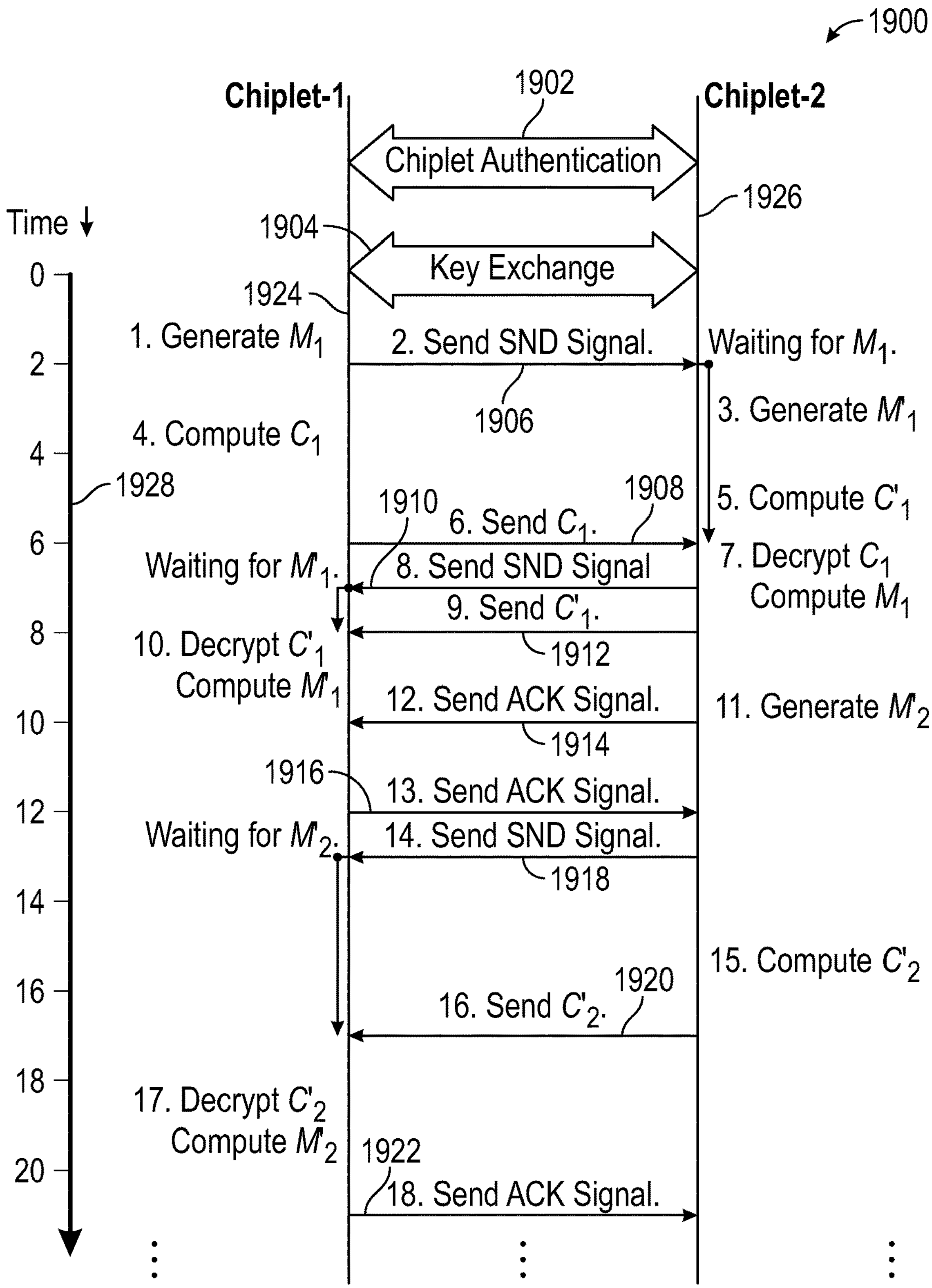
Full-Duplex Mode of Operation.

FIG. 17



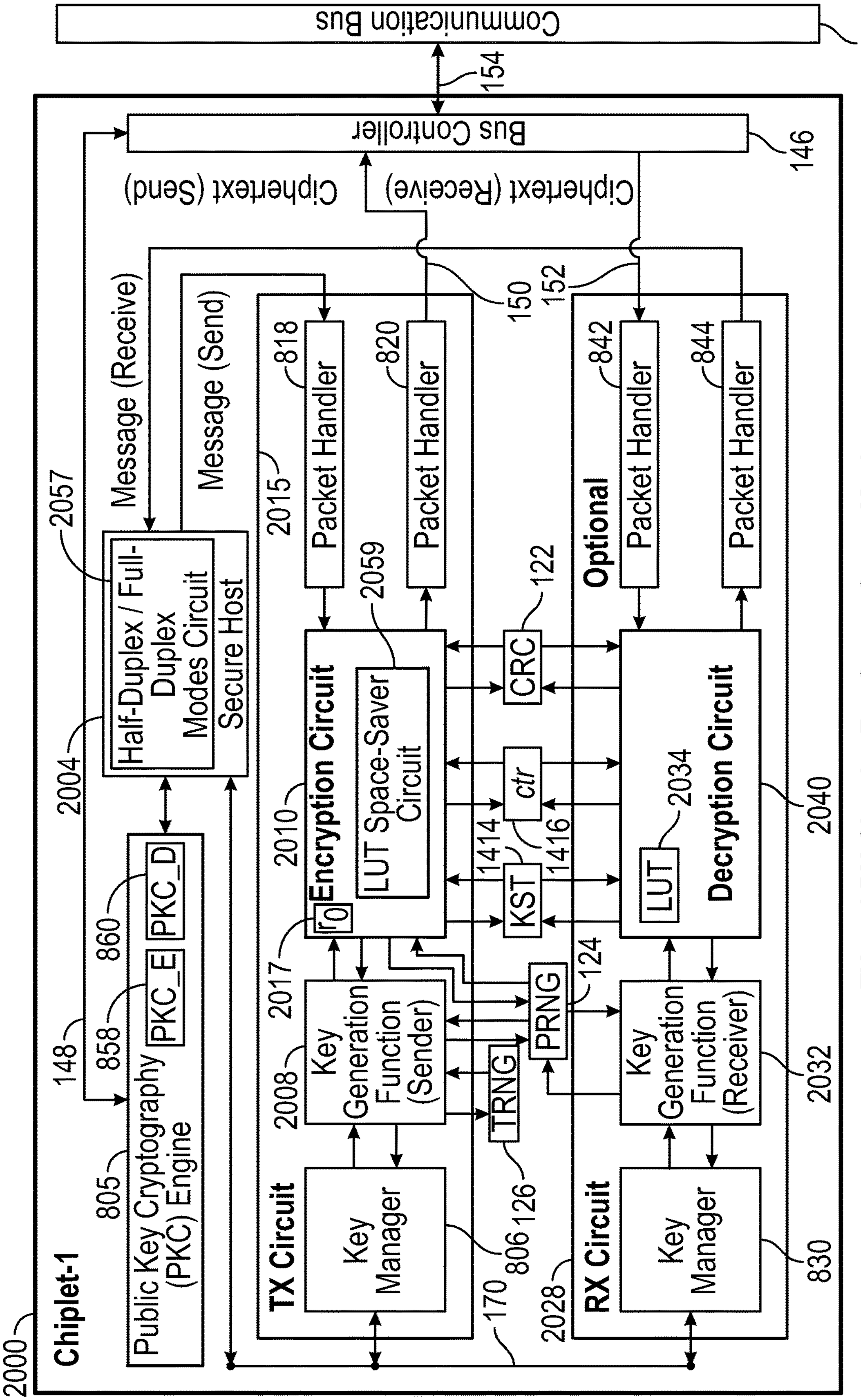
TX and RX Circuits For No-Delay Half-Duplex Mode.

FIG. 18



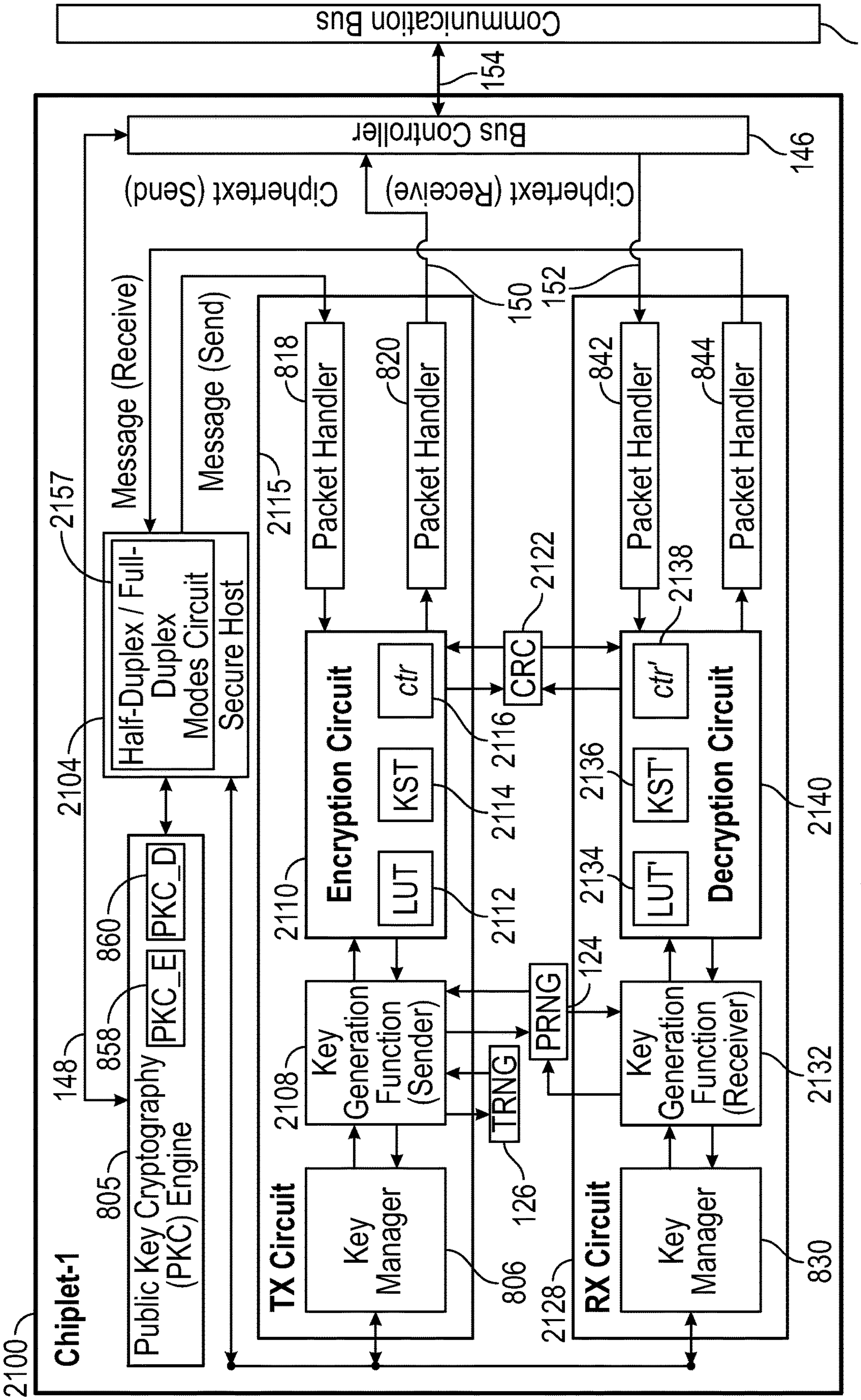
No-Delay Half-Duplex Mode of Operation.

FIG. 19



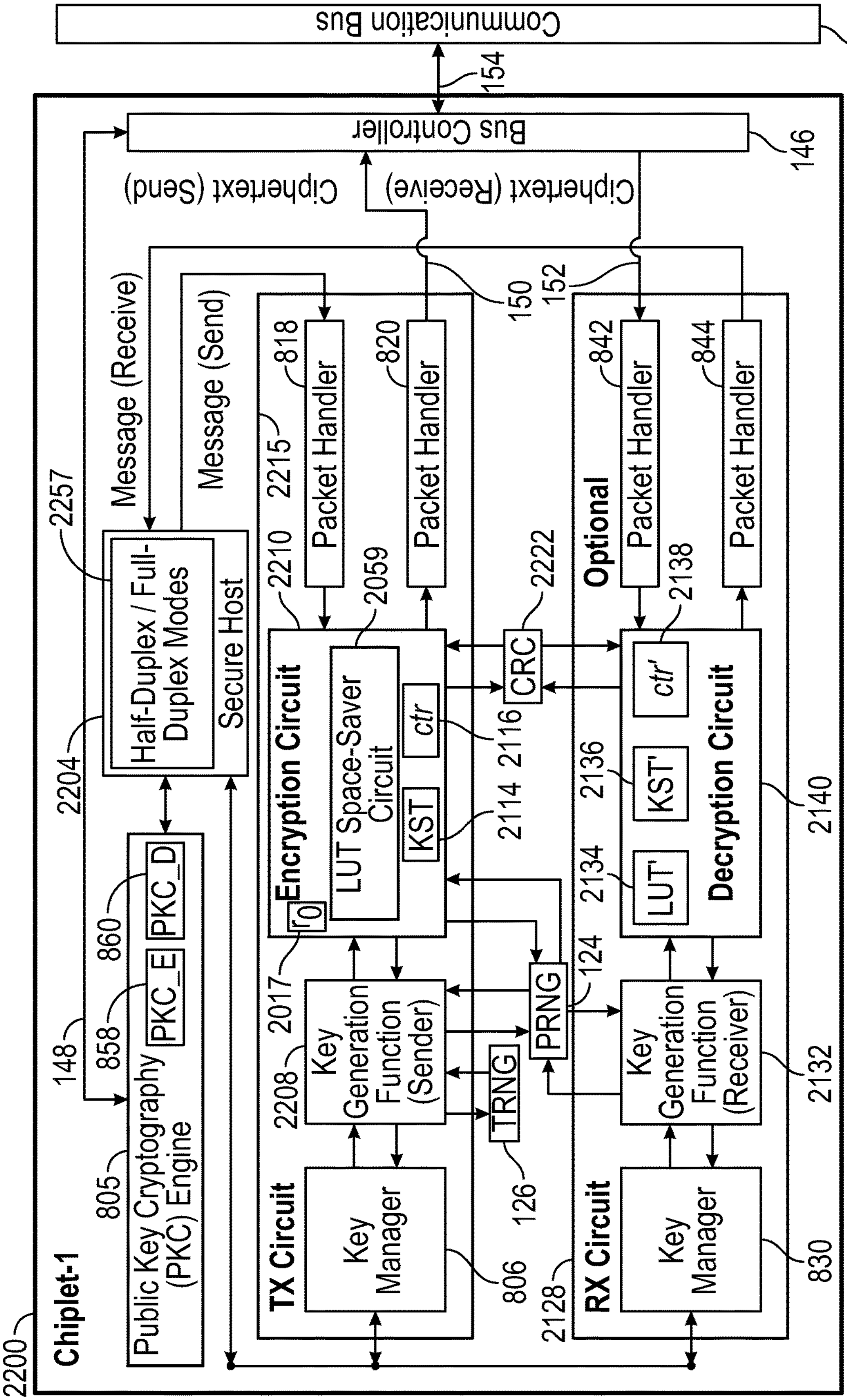
TX and RX Circuits For Space-Saver Mode.

FIG. 20



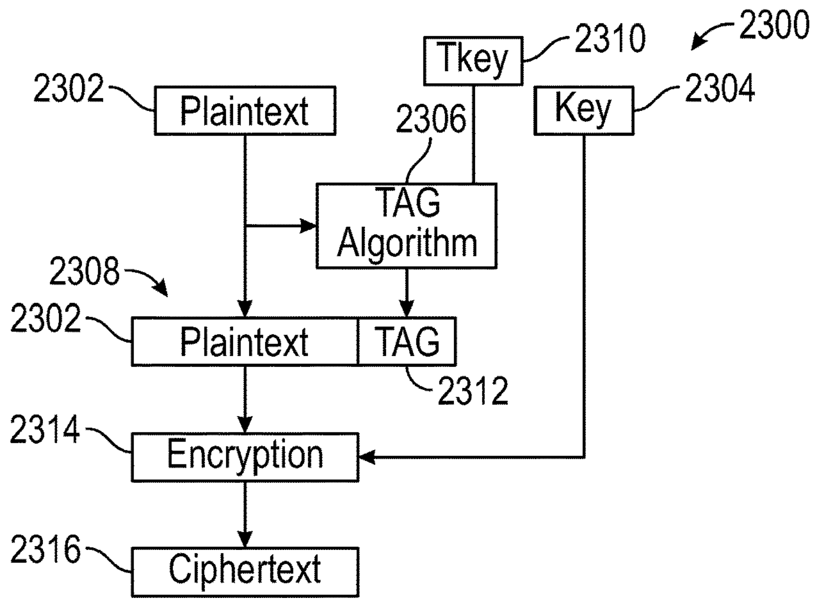
TX and RX Circuits For Two-Key Encryption Mode.

FIG. 21



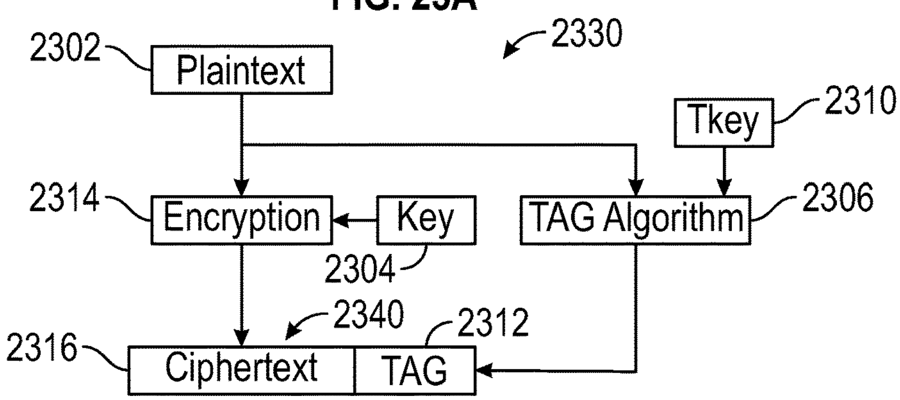
TX and RX Circuits For Two-Key Space-Saver Encryption Mode.

FIG. 22



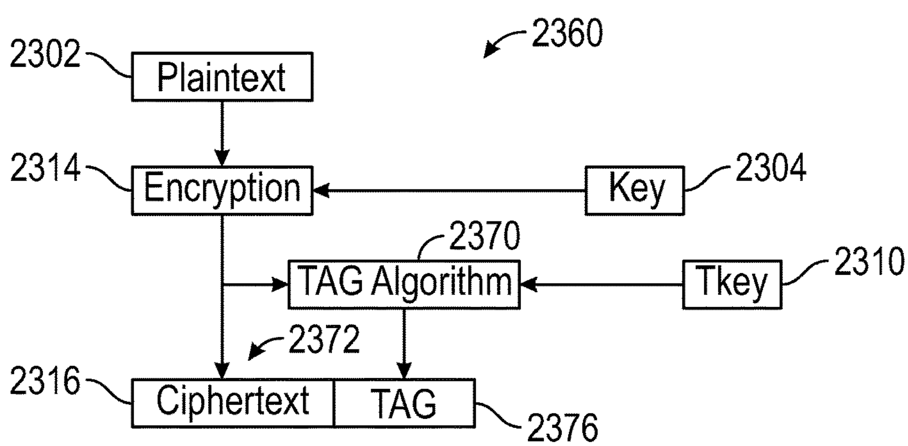
TAG-then-Encrypt

FIG. 23A



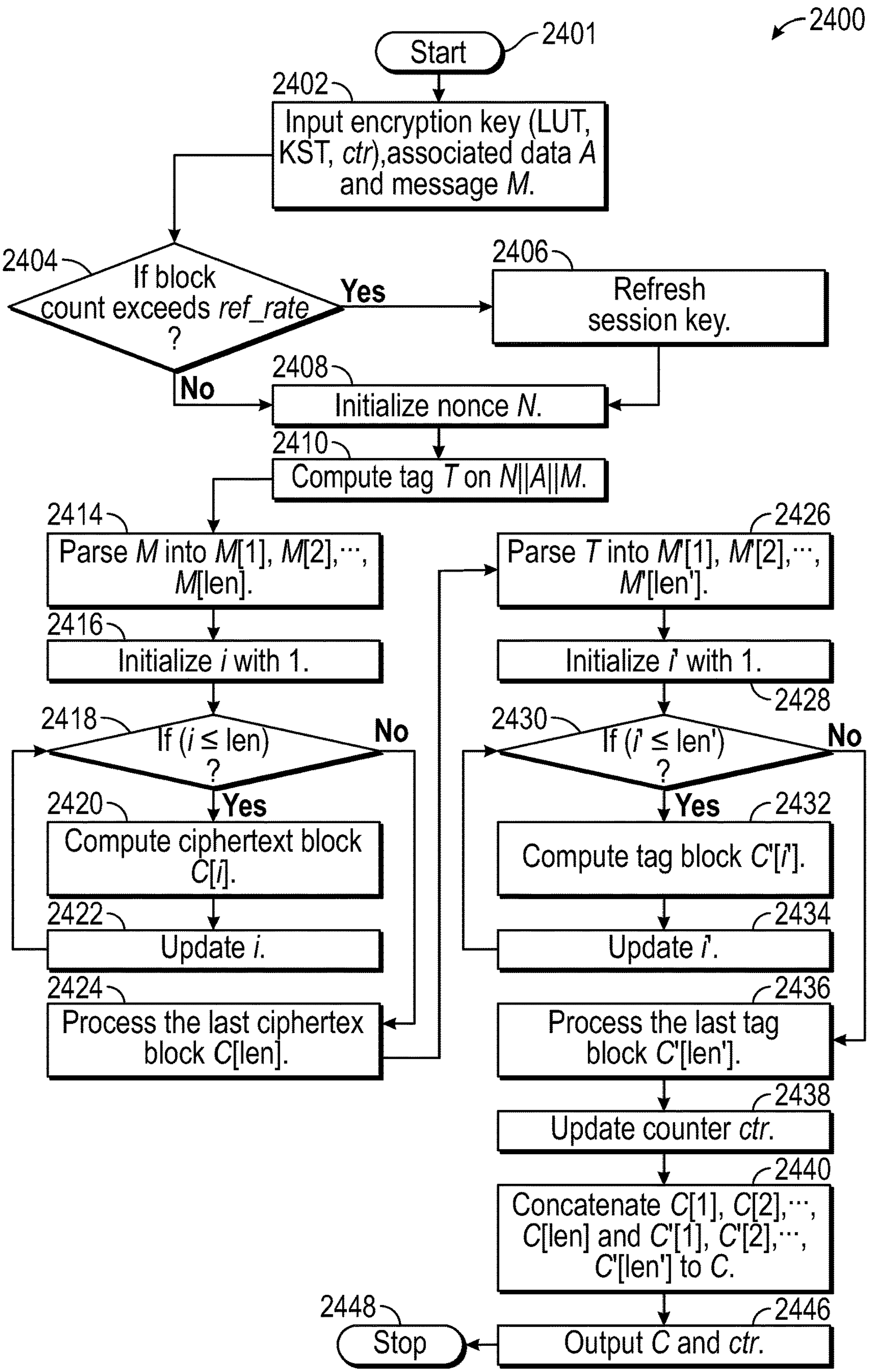
Encrypt-and-TAG

FIG. 23B



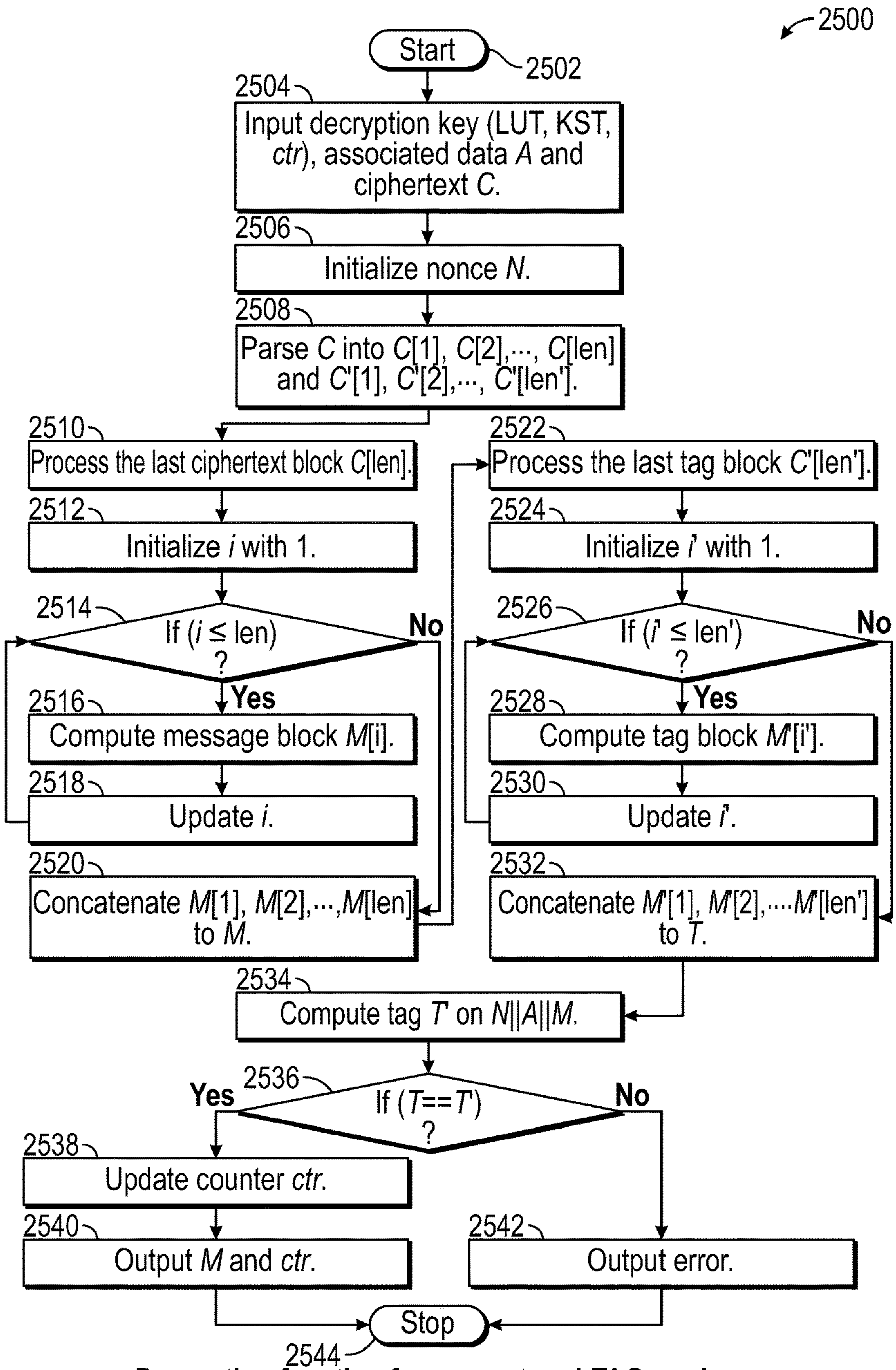
Encrypt-then-TAG

FIG. 23C



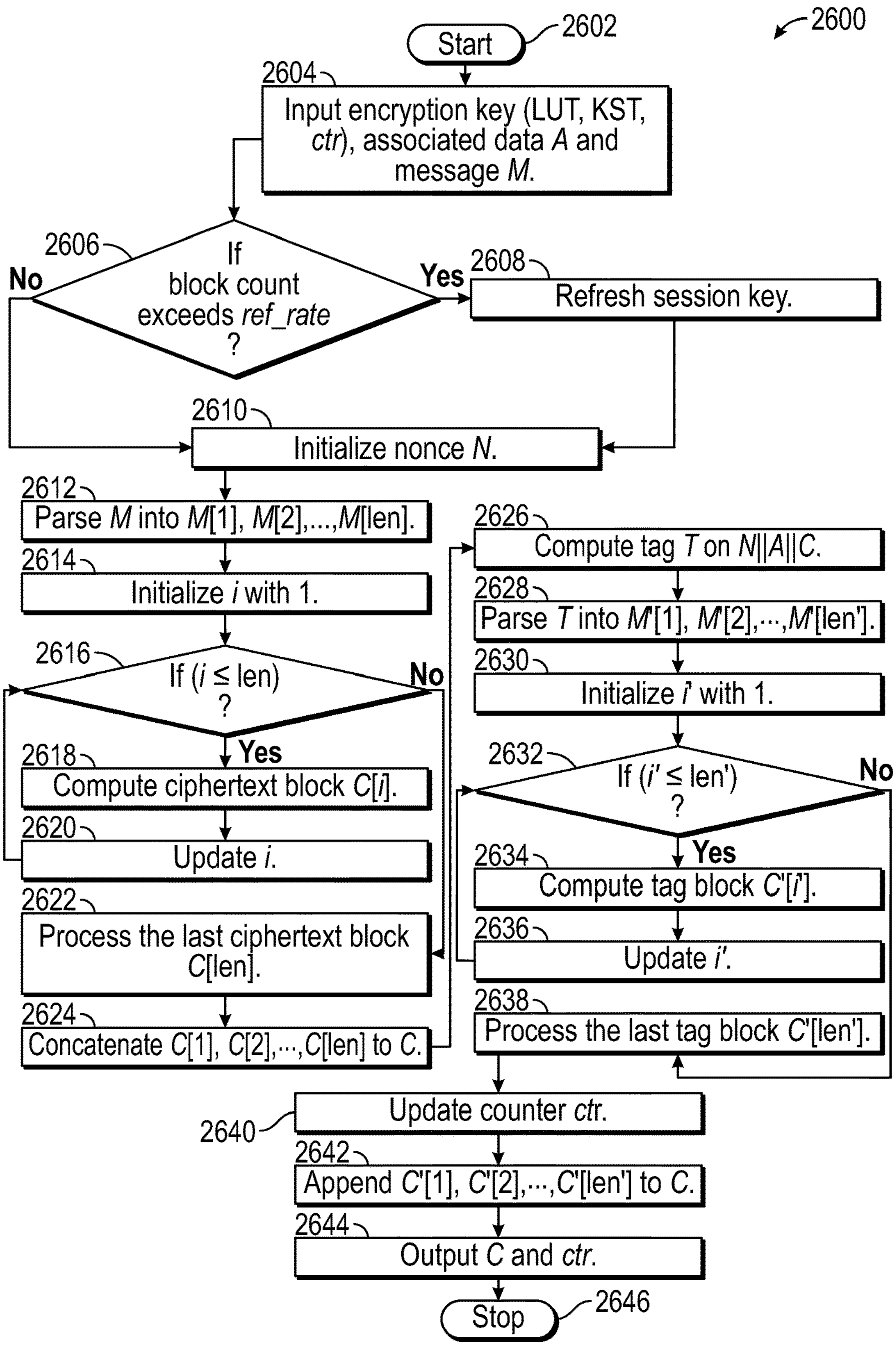
Encryption function for encrypt-and-TAG mode.

FIG. 24



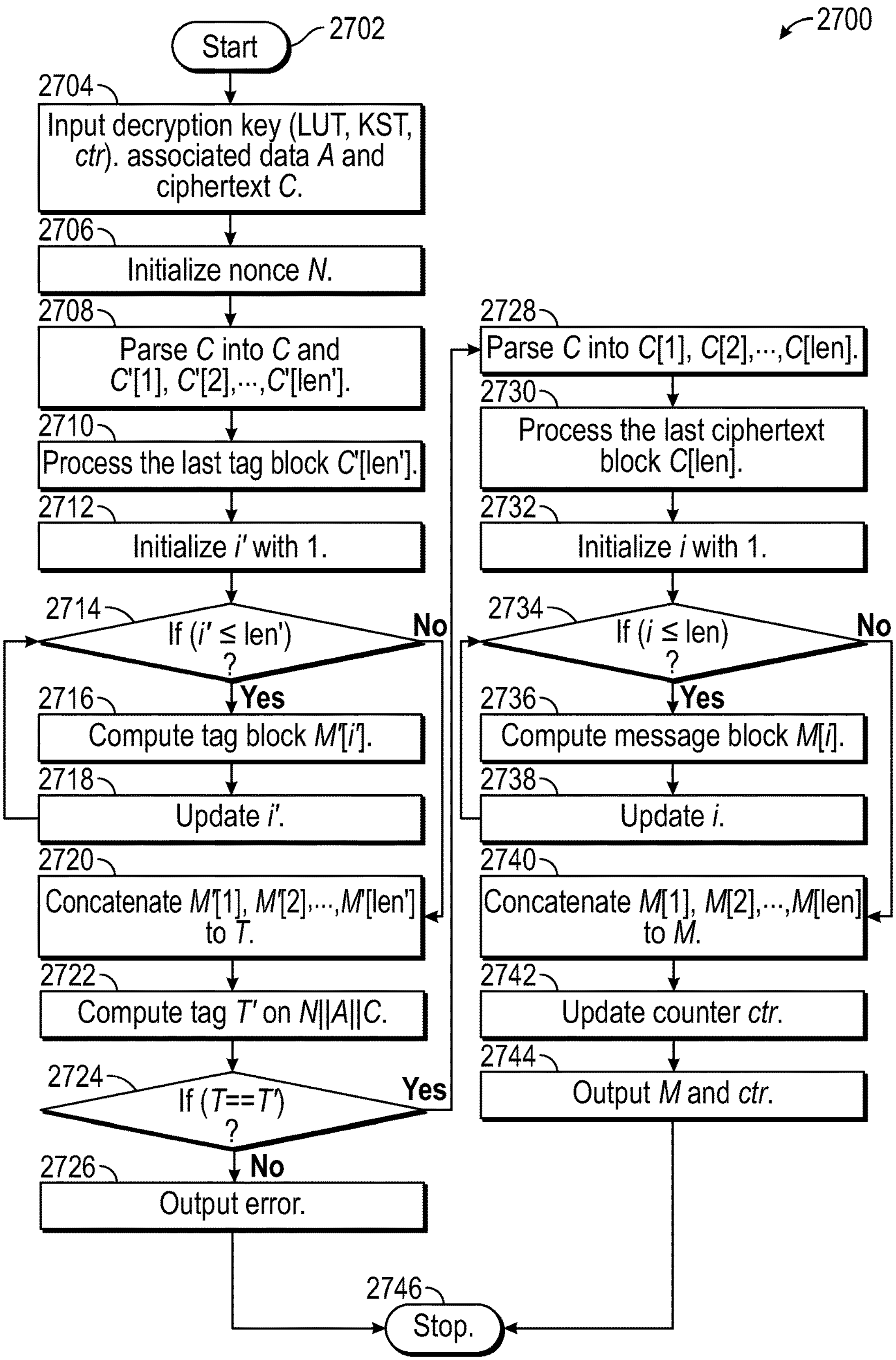
Decryption function for encrypt-and-TAG mode.

FIG. 25



Encryption function for encrypt-then-TAG mode.

FIG. 26



Decryption function for encrypt-then-TAG mode.

FIG. 27

LOOK UP TABLE (LUT) BASED CHIPLET TO CHIPLET SECURE COMMUNICATION

FIELD OF TECHNOLOGY

[0001] Some embodiments pertain to systems and methods for lookup table based encryption for chiplet-to-chiplet secure communication, and other embodiments pertain to lookup table based encryption with tagging for verification. In particular, some embodiments pertain to systems and methods for lookup table based encryption for secure communication that consumes fewer computing resources and other embodiments for tag-based verification.

BACKGROUND

[0002] A chiplet is an integrated circuit that is designed to be part of a larger whole. In some implementations, a chiplet is an independent unit for processing and computing. A chiplet may be a part of a package. In some implementations, a package may contain multiple homogenous or identical chiplets. A package may contain multiple heterogenous chiplets. A chiplet may also contain one or more sub-chiplets. A sub-chiplet is a dedicated hardware for a specific purpose, such as for example, an artificial intelligence engine, a machine learning engine, a communication circuit, or other fixed purpose. A chiplet may also be part of a larger integrated circuit, such as a computer processor.

[0003] Recently chiplets are part of a trend toward modular design of processors and other large integrated circuits. One reason for this is reduced cost if there is a defect. If there is a defect in a monolithic computer processor, the entire computer processor may have to be discarded. In contrast if there is a defect is a chiplet that forms part of a modular computer processor, only that one defective chiplet need be discarded.

[0004] Chiplets communicate with other chiplets via communication channels. Traditionally the security of these chiplet-to-chiplet communication channels has been given minimal importance. Yet, it is often important that chiplet-to-chiplet communication be as stable and error-free as possible. Applications where this is true include applications for detecting abnormal behavior in other applications and for transmitting sensitive data. Therefore secure communication between chiplets is desirable.

[0005] One challenge for secure chiplet-to-chiplet communication has been secure communication in resource-constrained devices. Resource-constrained devices include devices that are constrained in at least one of computing power, memory resources, or power supply. Examples of resource-constrained devices include, without limitation, smart cameras, smart home devices, smart telephones, routers and switches, and automotive devices. Another example is Internet-of-things (IoT) devices.

[0006] The above examples of resource-constrained devices have a variety of practical applications. For example, smart cameras have application in surveillance. Smart home devices may be useful for saving energy, home automation, and for convenience and comfort. Smart devices, such as telephones, have practical applications for monitoring health and for customized user experiences. Improved routers and switches may provide safer and quicker communication. And automotive computing devices have practical applications for safer transportation and for reliable communication among automotive components.

[0007] Many resource-constrained devices include chiplets and packages composed of chiplets. Secure and reliable communication between these chiplets is desirable for realizing the maximum practical benefits of these resource-constrained devices. Because these devices are resource-constrained, they need to have secure communication provided via lightweight protocols and technologies. Lightweight protocols and technologies are those that require at least one of fewer computer power, fewer memory resources, or less electrical power compared to a device that is not resource-constrained, such as for example, a server, a cloud computer, or a desktop computer.

[0008] Verification of received messages is important to secure communication. In particular, verification ensures that a received message does not have errors and has not been tampered with. Methods for verification are provided by cryptography. A common verification method uses hash functions. However, hash functions can be computationally expensive for resource-constrained devices.

SUMMARY

[0009] Some embodiments include a cryptographic method that is performed at least in part at a first chiplet. The method includes at least (1) with the first chiplet, parsing a message into at least one or more message blocks (2) dynamically generating at least a first target value that is associated with at least a first key (3) dynamically generating at least a second target value that is associated with at least a second key (4) encrypting at least one message block of the at least one or more message blocks to generate at least some ciphertext, the encryption being performed with at least one operation that includes at least one XOR operation, the at least one XOR operation being performed at least in part with the first target value and with at least the second target value, the first target value and the second target value being accessed at partly via the first and second keys, respectively; and (5) with at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet.

[0010] Some embodiments provide a cryptographic method performed at least in part at a second chiplet. The method includes (1) dynamically generating a first lookup table that includes a plurality of first target values and a plurality of first keys, a given first target value of the plurality of first lookup values being obtainable based on corresponding first key of the plurality of first keys, and wherein the first lookup table is at least one of usable or configurable as an inverse lookup table for obtaining the corresponding first key based at least in part on the given first target value, (2) dynamically generating at least a second lookup table that includes a plurality of second target values and a plurality of second keys, a given second target value of the plurality of second target values being obtainable based on a corresponding second key of the plurality of second keys, (3) decrypting at least one ciphertext block of one or more ciphertext blocks to generate at least some plaintext, the decryption being performed at least partly with one or more operations that include at least one or more XOR operations, the one or more XOR operations performed at least in part with the corresponding first key obtained at least partly via the given first target value and with at least the given second target value obtained at least partly via the corresponding second key, (4) verifying the at least some plaintext, and (5) outputting the at least some plaintext responsive to a successful verification of the plaintext.

[0011] Some embodiments include a cryptographic method that is performed in a first chiplet. The method includes at least (1) with one or more processing devices, computing a tag on a nonce, a message, and other data, (2) parsing the message into one or more message blocks to create one or more ordered message blocks, (3) encrypting the one or more ordered message blocks to obtain one or more ordered message ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations, (4) parsing the tag into one or more tag blocks to create one or more ordered tag blocks, (5) encrypting the one or more ordered tag blocks to obtain one or more ordered tag ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations, (6) concatenating the one or more ordered message ciphertext blocks with the one or more ordered tag ciphertext blocks to obtain final ciphertext, and (7) transmitting the final ciphertext to a second chiplet.

[0012] Some embodiments provide a cryptographic method that is performed in a first chiplet. The method includes at least (1) receiving a message for encryption, (2) encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations, (3) computing a tag on a concatenation that includes at least a nonce, the message ciphertext, and other data, (4) encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations, (5) appending the one or more ordered blocks of tag ciphertext to the message ciphertext to obtain final ciphertext, and (6) transmitting the final ciphertext to a second chiplet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] Representative embodiments are illustrated by way of example and not by limitation in the accompanying figures, in which:

[0014] FIG. **1** is a simplified block diagram of a resource-constrained device—a smart camera—in which some embodiments may be practiced.

[0015] FIG. **2** is a simplified block diagram of a package with which some embodiments may be practiced, showing the package as including a plurality of chiplets communicably linked with a plurality of communication channels.

[0016] FIG. **3** is a simplified block diagram of a first chiplet and a second chiplet that are communicably linked via an insecure channel, showing various components of both chiplets, consistent with some embodiments.

[0017] FIG. **4** is a simplified block diagram of an example chiplet consistent with some embodiments, showing first and second cores and various additional components.

[0018] FIG. **5** is a drawing of an exemplary lookup table (LUT), consistent with some embodiments, showing a first column with message data and a second column with target values.

[0019] FIG. **6** is a drawing of an exemplary key stream table (KST), consistent with some embodiments, showing a first column with index values and a second column with target values.

[0020] FIG. **7** is a drawing of an exemplary sorted inverse lookup table (designated LUT^{-1}), consistent with some embodiments, showing a second column of sorted target values.

[0021] FIG. **8** is a simplified block diagram of a chiplet consistent with some embodiments, showing encryption and decryption circuits with each storing a lookup table, a key stream table, and a counter (ctr).

[0022] FIG. **9** is a flow chart illustrating an exemplary method of key generation performed at a sending device, consistent with some embodiments.

[0023] FIG. **10** is a flow chart illustrating an exemplary method of key generation performed at a receiving device, consistent with some embodiments.

[0024] FIG. **11** is a flow chart illustrating an exemplary method of encryption, consistent with some embodiments.

[0025] FIG. **12** is a flow chart illustrating an exemplary method of decryption, consistent with some embodiments.

[0026] FIG. **13** is a sequence diagram showing an exemplary sequence of transmissions between two chiplets, consistent with some embodiments.

[0027] FIG. **14** is a simplified block diagram of a chiplet configured for basic half-duplex mode of communication, consistent with some embodiments.

[0028] FIG. **15** is a sequence diagram showing an exemplary sequence of transmissions between two chiplets, consistent with some embodiments, showing a basic half-duplex mode of communication.

[0029] FIG. **16** is a simplified block diagram of a chiplet configured for full-duplex mode of communication, consistent with some embodiments.

[0030] FIG. **17** is a sequence diagram showing an exemplary sequence of transmissions between two chiplets, consistent with some embodiments, showing a full-duplex mode of communication.

[0031] FIG. **18** is a simplified block diagram of a chiplet configured for no-delay half-duplex mode of communication, consistent with some embodiments.

[0032] FIG. **19** is a sequence diagram showing an exemplary sequence of transmissions between two chiplets, consistent with some embodiments, showing a no-delay half-mode of communication.

[0033] FIG. **20** is a simplified block diagram of a chiplet configured for a space-saver mode of communication, consistent with some embodiments.

[0034] FIG. **21** is a simplified block diagram of a chiplet configured for a two-key encryption mode, consistent with some embodiments.

[0035] FIG. **22** is a simplified block diagram of a chiplet configured for two-key space-saver mode, consistent with some embodiments.

[0036] FIG. **23**A is a sequence diagram, consistent with some embodiments, illustrating an exemplary sequence for performing a tag-then-encrypt mode.

[0037] FIG. **23**B is a sequence diagram, consistent with some embodiments, illustrating an exemplary sequence for performing an encrypt-and-tag mode.

[0038] FIG. **23**C is a sequence diagram, consistent with some embodiments, illustrating an exemplary sequence for performing an encrypt-then-tag mode.

[0039] FIG. **24** is a process flow diagram, consistent with some embodiments, illustrating an exemplary method for encryption using encrypt-and-tag mode.

[0040] FIG. **25** is a process flow diagram, consistent with some embodiments, illustrating an exemplary method for decryption using encrypt-and-tag mode.

[0041] FIG. **26** is a process flow diagram, consistent with some embodiments, illustrating an exemplary method for encryption using encrypt-then-tag mode.

[0042] FIG. **27** is a process flow diagram, consistent with some embodiments, illustrating an exemplary method for decryption using encrypt-then-tag mode.

DETAILED DESCRIPTION

[0043] In the above-described drawing, certain features are simplified to avoid obscuring the pertinent features with extraneous details. The above drawings are not necessarily to scale.

[0044] It is to be understood that the disclosed embodiments are merely exemplary of the invention, which may be embodied in various forms. It is also to be understood that multiple references to "some embodiments" are not necessarily referring to the same embodiments.

[0045] As used in this document "secure lightweight chiplet-to-chiplet communication" includes chiplet-to-chiplet communication that is secure but uses at least one of less computing power, less memory resources, or less electrical power as compared with at least some alternative modes of secure communication.

[0046] This document refers to various types of lookup tables. While a variety of terminology is used for lookup tables, as used in this document a lookup table contains key-value pairs, where the "key" is a first data item in a column that is used to look up a second data item in another column. The second data item will be referred to in this document as a "target value." In some embodiments lookup tables are implemented as table data structures.

[0047] As used in this document, a "dynamic" structure or event is a structure or event that is constructed or performed by executing programs during runtime or "on the fly." In contrast, a static structure refers to a structure that is constructed at compile-time, before runtime.

[0048] This document refers to dynamic substitution boxes, which in some embodiments are a lookup table (LUT). Accordingly, this document interchangeably refers to either dynamic substitution boxes or LUT's.

[0049] This document uses the term inverse LUT or LUT^{-1}. An inverse LUT is an LUT but used in reverse. As discussed above, a key in an LUT is used to access a target value. But when an LUT is used or configured as an inverse LUT, the target value is used to access the key. Inverse LUT's are discussed in detail relative to FIG. **6** below.

[0050] This document refers to dynamic keystream tables (KST's), which in some embodiments are a table data structure. This document interchangeably refers to either dynamic keystream tables or KST's. A KST is also a type of look-up table, but this document does not refer to KST's as LUT's or LUT^{-1}'s.

[0051] This document uses the term "tag" to refers one or more of a cyclic redundancy check (hereinafter "CRC"), hash function, or the like.

[0052] This document frequently refers to the term counter, often designated as "ctr."

[0053] This document uses the term "session key" to refer to a concatenation of two random or pseudorandom bits designated r_0 and r_1, the concatenation being $r_0||r_1$. In some of the embodiments discussed below, a session key is used to generate an LUT and a KST. These and related concepts are described in more detail below. In some of that discussion, the letter "K" is used to refer to a session key.

[0054] In describing some embodiments, this document uses the term "encryption key" to refer to a collection of data structures and data. For example, with respect to some embodiments, an encryption key is a tuple that includes an LUT, a KST, and a ctr. With respect to some other embodiments, an encryption key includes random or pseudo-random bits r_0, a KST, and a ctr. In describing some embodiments, this document uses the term decryption key similarly. Specifics of the contents of an "encryption key" or a "decryption key" are discussed below with reference to specific embodiments.

[0055] Some mathematical expressions used in this document are:

[0056] a. λ (lambda) which in this document refers to a security parameter; and

[0057] b. $\oplus$ which indicates a bitwise XOR operation.

[0058] There is a need for secure lightweight chiplet-to-chiplet communication. In particular, there is a need for encryption and decryption technologies that avoid or minimize use of resource-intensive multiplication operations. And there is a need for technologies for verifying the integrity and authenticity of messages while avoiding or minimizing resource-intensive hash functions.

[0059] This need for secure lightweight chiplet-to-chiplet communication is especially relevant for resource-constrained devices, which as used herein, refers to a computing device that is constrained in at least one of computing power, memory resources, or power supply. One example of a resource-constrained device is an Internet-of-Things (IoT). Other examples of resource-constrained devices include, without limitation, smart cameras, smart home devices, smart telephones, routers and switches, and automotive devices. Examples of computing devices that are not resource-constrained, for purposes of this document, are servers, powerful cloud-based computers, and desktop computers.

[0060] Practical applications for resource-constrained devices with secure lightweight chiplet-to-chiplet communication include, for example, surveillance, energy efficiency, home automation, health monitoring, secure and efficient communication, and better functioning machines, such as automobile engines.

[0061] Embodiments described herein provide such secure lightweight chiplet-to-chiplet communication. For example, some embodiments provide for communication between a pair of chiplets linked by a communication link. In some embodiments, the pair of chiplets are part of numerous chiplets, and corresponding communication links, in a package. In some embodiments a pair of chiplets are on the same die. In some embodiments, a pair of chiplets reside on different dies and are linked by a series of network communication links. In some embodiments, two chiplets may communicate with each other across a network.

[0062] Embodiments described herein may provide a variety of services, such as for example, one or more of the following services:

[0063] a. Lightweight methods of encryption and decryption of messages;

[0064] b. Tag computation and verification; and

[0065] c. Support for various modes of communication between chiplets.

[0066] Not all embodiments provide all of the above services. For example, in some embodiments chiplets communicate via a communication link that does not support encryption or decryption. In some embodiments, tag computation and verification are not performed. And some embodiments are limited in their modes of communication.

[0067] Turning first to lightweight methods of encryption and decryption, some embodiments described herein use at least a portion of a dynamic substitution box (LUT). In contrast to a static substitution box, an LUT is computed at runtime, for example, during execution of an encryption or decryption function. An LUT is a lookup table in which the keys are bits representing message blocks and the target values are substitution values composed of at least one of randomly or pseudo-randomly selected bits. In some embodiments the keys are sorted. Thus, if one has a message block to encrypt, the LUT facilitates locating a key corresponding to the message block and accessing the corresponding target value, which is the substitution value (bits).

[0068] In some embodiments. the LUT is a table. In some embodiments, the LUT is stored in memory of a chiplet and in some further embodiments is 4 MB or less in size. And in some particular embodiments, the LUT is a table which is both stored in memory of a chiplet and is 4 MB or less in size. For example, an LUT may be 4 MB in size when the keys are only 16 bits and target values are only 512 bits. The sizes of the keys and the target values are discussed later in this document.

[0069] In some other embodiments, encryption is performed in part by dynamically computing one or more needed target values of the LUT and the entire LUT is not computed or stored in memory. This approach allows resource-constrained device to save on computation and memory resources.

[0070] Some embodiments additionally use a dynamic keystream table (KST). The KST is a lookup table in which the keys are numerical index values (e.g. blocks of bits) organized in numerical order. And the target values for a KST are at least one of random and pseudo-random blocks of bits. A KST thus matches numerical index values with corresponding random or pseudo-random blocks of bits.

[0071] Thus, KST's are useful for encrypting, for example, an ordered plurality of message blocks. In some embodiments, the key (the numerical index value) is a number that corresponds to a position of a message block within the ordered plurality of message blocks. If one has the position of the message block within the ordered plurality of blocks, then a KST facilitates locating an index value (a key) that corresponds to that position and then assigning that position a corresponding target value (e.g. a random or pseudo-random block of bits). Therefore, when used to create ciphertext, the use of a KST provides positional information within the ciphertext. KST's are useful for thwarting attacks by a "man in the middle" who as part of an attack reorders ciphertext blocks.

[0072] Although the KST is referred to as a "table", the use of the word table in this document is not intended to preclude using other types of data structures. In some embodiments an entire KST is computed and stored in memory of a chiplet. In other embodiments, a KST is neither computed nor stored in memory. Instead, target values of a KST are computed dynamically, on the fly as needed.

[0073] The LUT and the KST are also used for decryption. When an LUT is used for decryption, it is used or configured as an inverse LUT. That is, the target values which are the randomly or pseudo-randomly selected block of bits are mapped back to the bits representing the message blocks (the keys). For LUT's decryption requires that an LUT be used or be configured to be used as an inverse lookup table.

[0074] When a KST is used for decryption, it is used in the exact same way as used during encryption. That is, the keys are numerical index values (e.g. blocks of bits) organized in numerical order and the target values for a KST are at least one of random and pseudo-random blocks of bits. A KST thus matches numerical index values with corresponding random or pseudo-random blocks of bits.

[0075] Use of the LUT and of the KST may result in replacing computationally expensive multiplication operations used in some encryption and decryption protocols. Thus, encryption and decryption are less computationally expensive for resource-constrained devices.

[0076] Some embodiments also replace computationally-expensive hash-based functions, which are commonly used to verify data integrity, with a lightweight CRC which in some embodiments is concatenated with and encrypted along with the message. Computation of a CRC is less computationally-expensive than computing a hash function. Replacing hash functions with CRC's in many cases causes computationally-expensive multiplication to be replaced by less computationally-expensive shift and XOR operations.

[0077] Some embodiments provide one or more of five new modes of communication between chiplets. As compared with traditional half duplex and full duplex, these new modes of communication provide one or more of faster communication with fewer waiting times, reduced data storage requirements, higher security, or higher performance. More details on these are provided below.

[0078] Thus, in some embodiments, a cryptographic method performed at least in part with one or more chiplets includes at least providing a message (e.g. a message M) for encrypting at a first computing device, parsing at least the message into at least one message (e.g. M[i]) block that contains first message data (e.g. a block of the message itself) and that is associated with a first index value (e.g. i), dynamically computing at least one row of a first lookup table (e.g. at least one row of a dynamic substitution box), the at least one row of the first lookup table including at least second message data and at least a first target value (e.g. intermediate ciphertext) associated in the at least one row of the first lookup table with the second message data, at least in part with the first message data, accessing the at least one row of the first lookup table to obtain the first target value, dynamically computing at least one row of a second lookup table (e.g. at least one row of a dynamic keystream table), the at least one row of the second lookup table including at least a second index value and a second target value associated in the at least one row of the second lookup table with the second index value, at least in part with the first index value, accessing the at least one row of the second lookup table to obtain the second target value, computing at least some ciphertext with at least one operation with at least the first lookup value and the second lookup value, the at least one operation including at least an XOR operation, and with at least one processing device transmitting the at least some ciphertext from the first computing device to a second computing device.

[0079] Referencing FIG. 1, a resource-constrained device, such as smart camera 1 provides an environment in which some embodiments may be at least partially practiced. Smart camera **1** includes lens **2** coupled or integral with housing **10**. Housing **10** includes a processing device such as CPU **8**. Housing **10** further includes artificial intelligence resources such as for example AI engines **5**A-**5**D, ethernet interface **9**, compression circuitry **7**, and image processor **6**, each of which is communicably linked with CPU **8**. An optical filter **3** and an image sensor **4** are provided and are positioned to capture and process light entering lens **2**. As has been discussed above, smart camera **1** is just one example of a resource-constrained device.

[0080] Referencing FIG. **2**, a package **100** includes a plurality of chiplets, including for example chiplets **101**A-**101**D. In some embodiments, package **100** is a component of a processor, such as for example CPU **8** of FIG. **1**. The various chiplets, for example chiplets **101**A-**101**D, are communicably linked with one or more other chiplets via communication links, such as communication links **102**A-**102**D.

[0081] Referencing FIG. **3**, a network **300** includes chiplets **305**A, **305**B and an insecure channel **330** (e.g. a bus) communicably linking chiplets **305**A and **305**B. Chiplet **305**A includes communication sub-chiplet **301**A (same as the transceiver circuit **113** of FIG. **4** which is implemented as a communication sub-chiplet) which includes TRNG **328**A (a true random-number generator), $PRNG_0$ **322**A and $PRNG_1$ **324**A (both pseudo-random number generators), a CRC generator **326**A, an LUT **310**A and a KST **320**A. TRNG **328**A is configured to output true random numbers, such as for example, true random numbers r0 (**327**A) and r1 (**327**B).

[0082] Similarly, Chiplet **305**B includes communication sub-chiplet **301**B which includes TRNG **328**B (a true random-number generator), $PRNG_0$ **322**B and $PRNG_1$ **324**B (both pseudo-random number generators), a CRC generator **326**B, an LUT **310**B and a KST **320**B.

[0083] In some embodiments, communication sub-chiplet **301**A is configured to send an encrypted message (not shown) to communication sub-chiplet **301**B via insecure channel **330**. Communication sub-chiplet **301**A encrypts the message in part with LUT **310**A and KST **320**A. Communication sub-chiplet **301**B receives the encrypted message (ciphertext) and decrypts it in part with LUT **310**B and KST **320**B. In some embodiments, LUT's **310**A and **310**B are identical and KST's **320**A and **320**B are identical.

[0084] In some embodiments, communication sub-chiplet **301**A generates LUT **310**A and KST **320**A. In some embodiments, this is performed by communication sub-chiplet **301**A first generating true random numbers r0 (**327**A) and r1 (**327**B) with TRNG **328**A. The true random number r0 is input as a seed into $PRNG_0$ **322**A and true random number r1 is input as a seed into $PRNG_1$ **324**A. Communication sub-chiplet **301**A then uses $PRNG_0$ **322**A to generate the LUT **310**A. Communication sub-chiplet **301**A uses $PRNG_1$ **324**A to generate the KST **320**A. Communication sub-chiplet **301**A uses public key cryptography (e.g. PKC Engine **105** of FIG. **4**) to provide the true random numbers r0 (**327**A) and r1 (**327**B) via insecure channel **330** to communication sub-chiplet **301**B, which then provides the true random numbers r0 (**327**A) and r1 (**327**B) to $PRNG_0$ **322**B and $PRNG_1$ **324**B, respectively, for use as a seed. Communication sub-chiplet **301**B then uses $PRNG_0$ **322**B to generate the LUT **310**B and $PRNG_1$ **324**B to generate the KST **320**B.

[0085] In some embodiments, true random number generators, such as for example TRNG's **328**A, **328**B, are hardware-based true random number generators. A hardware-based true random number generator generates random numbers based on physical phenomena rather than based on algorithms. Some examples of these physical phenomena are thermal noise, random noise signals, photoelectric effects, quantum effects, and other physical phenomena.

[0086] In some embodiments, pseudo-random number generators, such as for example, $PRNG_0$ **322**A and $PRNG_1$ **324**A are deterministic random number generators that generate pseudo-random numbers based on an algorithm. In some embodiments they are seeded at least in part with a random number or a pseudo-random number. Pseudo-random number generators are sometimes used instead of true random number generators because of reduced computational overhead.

[0087] Referencing FIG. **4**, a chiplet **400** is disclosed in which some embodiments may be practiced. Chiplet **400** includes a secure host **104** (e.g. secure processing circuitry such as for example one or more processors). Consistent with some embodiments, chiplet **400** further includes at least core-1 (**107**A) and core-2 (**107**B), an ML engine **109** (a machine-learning engine), and an AI engine **111** (an artificial intelligence engine), all of which are communicably linked with secure host **104**. Chiplet **400** further includes transceiver circuit **113** that is communicably linked with secure host **104**. Transceiver circuit **113** includes TX Circuit **115** (a transmission circuit), an RX Circuit **128** (a receiver circuit), a TRNG engine **126** (a true random number generator engine), a PRNG engine **124** (a pseudo-random number generator engine), and a CRC engine **122** (a cyclic redundancy check engine). In some embodiments, CRC engine **122** accepts an input a message **117**, a nonce **119**, and some associated data **121** for generating a CRC.

[0088] Although TX Circuit **115** and RX Circuit **128** are at least similar, respectively, to communication sub-chiplet **301**A (sender) and to communication sub-chiplet **301**B (receiver), there are some differences. For example, in FIG. **3**, communication sub-chiplet **301**A includes $PRNG_0$ **322**A, $PRNG_1$ **322**B, TRNG **328**A, CRC **326**A, LUT **310**A, and KST **320**A. And similarly, communication sub-chiplet **301**B includes $PRNG_0$ **322**B, $PRNG_1$ **322**B, TRNG **328**B, CRC **326**B, LUT **310**B, and KST **320**B. That is, communication sub-chiplets **301**A, **301**B do not share the foregoing internal components. In contrast, TX Circuit **115** and RX Circuit **128** share (e.g. in a shared memory—not shown), TRNG engine **126**, PRNG engine **124**, and CRC engine **122**.

[0089] TRNG engine **126**, PRNG engine **124**, and CRC engine **122** are each communicably linked with, and therefore accessible to, both TX circuit **115** and RX circuit **128**. Each of TX circuit **115** and RX circuit **128** are communicably linked with secure host **104** via communication link **170**. Chiplet **400** further includes a public key cryptography engine **105** ("PKC engine") that is communicably linked with secure host **104**.

[0090] Continuing with reference to FIG. **4**, Chiplet **400** further includes a bus controller **146**, a communication bus **156**, and a communication link **154** that communicably links bus controller **146** with communication bus **156**. Bus controller **146** is communicably linked with PKC engine **105** via communication link **148**, with TX circuit **115** via communication link **150**, and with RX circuit **128** via communication link **152**.

[0091] Referencing FIG. **5**, LUT **500** is organized as a table data structure that defines rows and columns. Those skilled in the art will recognize that a table may include rows and columns which can be organized as arrays or multi-dimensional arrays. Those skilled in the art, after having been appraised of the principles described herein, will recognize that a variety of implementation choices are possible. All are within the scope of this disclosure. For simplicity this document will refer to rows and columns of a table data structure.

[0092] LUT **500** includes a first column **502** of bits (e.g. such as 0000, 0001, 0010, 0011 as shown) that define message blocks **502**A-**502**F (the keys of the LUT). These bits are the actual content of a message M divided into message blocks. After a message is divided into blocks, the message blocks are numerically sorted. The result is message blocks **502**A-**502**F as shown.

[0093] LUT **500** also includes a second column **504** with blocks of substitution bits **504**A-**504**F (e.g. LUT[0], LUT [1], LUT[2], LUT[3], . . . LUT [2^b−2], LUT [2^b−1]) for the corresponding message blocks **502**A-**502**F. The blocks of substitution bits **504**A-**504**F are at times also referred to as target values because they can be accessed in LUT **500** via the message blocks **502**A-**502**F (the keys) of the first column **502**. That is, one may access a message block such as message block **502**A and thereby access target value LUT[0] (**504**A).

[0094] Further referencing FIG. **5**, LUT **500** defines rows **501**A-**501**F that include both a message block and its associated block of substitution bits. For example, row **501**A includes both message block **502**A which contains bits 0000 (e.g. 0000) and its corresponding block of substitution bits **504**A, denominated LUT[0].

[0095] In this example, the message blocks defining column **502** are b bits wide. And the corresponding substitution bits defining column **504** are w bits wide. This results in ciphertext blocks that are w bits wide. For increased security of the ciphertext, the value w is generally greater than the value of b. For example, in an exemplary embodiment, b is 16 bits and w is 256 bits. Other values for b and w are of course possible. For example, where increased security is desirable w is 512 or perhaps 1024. The variables b and w are relevant to various embodiments discussed below and will be discussed below as needed.

[0096] The value b determines how many rows are in columns **502** and **504**, specifically 2^b. But because message block **502**A has bits equal to zero (0000), the last row **502**F has bits equal to 2^b−1. As discussed below, in some embodiments, b and w are set by a security parameter λ.

[0097] An example showing organization of sample message blocks is now discussed. A message M (**511**) consists of bits 0001000000110010. This message M is divided into blocks M[0]=0001, M[1]=0000, M[2] 0011, and M[3] =0010. These blocks are then used to define column **502** of LUT **500**. But before being used to form column **502**, the blocks are numerically sorted. It can be seen that the bits in message blocks **502**A-**502**D are numerically sorted to be in numerical order: 0000, 0001, 0010, 0011. These message blocks are the keys for the LUT **500**. LUT[0] is then the block of substitution bits for 0000, LUT[1] is the block substitution bits for 0001, LUT[2] is the block of substitution bits for 0010, and LUT [3] is the block of substitution bits for 0011. And LUT[0]-LUT[3] are target values for LUT **500**. Then one intending to find the substitution bits for 0010 would search column **502** for the row (row **501**C) with bits 0010, which is a key. Once the key is found, one then finds the corresponding block of substitution bits as LUT[3] (the target value).

[0098] Referencing FIG. **6**, KST **600** is organized as a table data structure that defines rows and columns. Those skilled in the art will recognize that a table may include rows and columns which can be organized as arrays or multi-dimensional arrays. Those skilled in the art, after having been appraised of the principles described herein, will recognize that a variety of implementation choices are possible. All are within the scope of this disclosure. For simplicity this document will refer to rows and columns of a table data structure.

[0099] KST **600** includes a first column **612** that includes the index values from 0 to (2^b-1), (**612**A-**612**F) where b is number of bits in the index values. The value b also determines the number of rows (**601**A-**601**F) in the KST. For example, if b is 4, then each index value has 4 bits and the number of rows in the KST is 2^4=16. The index values **612**A-**612**F are the keys for looking up the target values, which are discussed next.

[0100] KST **600** has a second column **614** with target values that comprise random or pseudo-random blocks of bits that correspond to the index values (the keys) in column **612**. For example, target value KST[0] corresponds to index 0 (its key) where KST[0] is a block of random or pseudo-random bits. Thus, for index values 0 to (2^b-1) of column **612** (reference numbers **612**A-**612**F), the corresponding target values are KST[0]-KST[2^b-1] of column **614** (reference numbers **614**A-**614**F). Thus, if one seeks the target value that correspond to index 3 (index value **612**D in row **601**D), then the corresponding target value is KST[3] (**614**D).

[0101] KST **600** may also be seen as organized into rows **601**A to **601**F, where each row has an index value (e.g. index value 0 of row **601**A) and a corresponding target value (e.g. KST[0] of row **601**A).

[0102] The number of bits in the blocks of random or pseudo-random bits of the target values (**614**A-**614**F) is w, which is set based on security levels. Generally, if other factors are held constant, as w increases the security level also increases.

[0103] The index values **612**A-**612**F are associated with positions of message blocks and may be regarded as position values. For example, returning to FIG. **5** to reference ordered message blocks M[0], M[1], M[2], M[3], the numbers in brackets are index values. For example, for message block [3] the number 3 is an index value (e.g. index value 3 (**612**D in row **601**D in KST **600**) associated with the position of message block M[3] within the ordered message blocks M[0], M[1], M[2], M[3]. If a message block changes positions between encryption and decryption (e.g. if moves from position 3 to position 2) the KST will provide one target value during encryption and a different target value (based on the different position) for decryption and an error will result, because of which, during decryption, it is highly unlikely to get the correct key value in the inverse LUT from the obtained target value. Thus, the KST can be used to detect a change in an ordering of blocks, perhaps the result of an attack.

[0104] Returning to reference FIG. **5**, when LUT **500** is used for encryption, the keys (message blocks **501**A-**501**F) are used to access the corresponding target values (e.g. blocks of substitution bits **504**A-**504**F). However, during decryption, this operation is reversed. That is, the target values (e.g. blocks of substitution bits **504**A-**504**F) are used to access the keys (message blocks **501**A-**501**F). Therefore, if one has a target value there is a way to find the target value's corresponding key. If one has a target value and can find the target value in column **504**, then the corresponding message block is the message block that shares the same row as the target value in LUT **500**.

[0105] In FIG. **5** the target values LUT[0]-LUT[2^b-1] are blocks of random or pseudo-random bits. These blocks of random or pseudo-random bits are not in any particular order. Instead, the rows (**501**A-**501**F) of the LUT **500** are sorted according to the numerical values of the bits of the message blocks (**502**A-**502**F).

[0106] But there are times when it is necessary to find a particular target value. For example, if during decryption a ciphertext block has bits xxxx (i.e. arbitrary bits), then one needs to determine which target value has bits that match xxxx. One can compare those bits xxxx to the bits in the target values of column **504** to locate the target value with the correct matching bits. If the bits xxxx match the bits of LUT[2], then one can determine that LUT[2] is in row **501**C and that the corresponding message block in row **501**C is message 0010 (**502**C). That raises the issue of how one searches column **504** for the target value with the desired block of bits. There are at least two possible scenarios.

[0107] In the first scenario, the target values in column **504** are not sorted. That is, the blocks of random or pseudo-random bits defining the target values of column **504** are not organized in any particular order. In this scenario, one may search column **504** of LUT **500** for the target value that matches a desired pattern of random or pseudo-random set of bits. In one embodiment, this is a linear search. A linear search cannot be replaced by, for example, binary search because binary search requires a sorted set of values, (e.g. a sorted list). While an LUT with unsorted target values in its second column may be used as an inverse LUT (e.g. where keys are accessed based on their corresponding target values), the linear search takes time and computational resources. Nevertheless, this is one option. An LUT with unsorted target values in its second column can be used as an inverse LUT. But, there is at least one other scenario, discussed below.

[0108] Referencing FIG. **7** a sorted inverse LUT **700** is discussed. The content of sorted inverse LUT **700** (i.e. LUT^{-1}) is the same as the content of LUT **500** except that the rows **701**A-**701**F have been sorted according to their target values (**714**A-**714**F) in the second column **714**. Specifically, the target values of column **714** are sorted to achieve and ordering in which: $LUT[i_0]<LUT[i_1]$, $LUT[i_1]<LUT[i_2]$, $LUT[i_2]<LUT[i_3]$ and $LUT[i_{2^b-2}]<LUT[i_{2^b-1}]$. Rows **701**A-**701**F and message blocks **712**A-**712**F of first column **712** are ordered consistently with the sorted target values. This means that the blocks of random and pseudo-random bits that define target values $LUT[i_0]$-$LUT[i_{2^b-1}]$ are ordered. They may be searched with an efficient non-linear search algorithm, such as binary search.

[0109] For example, if one searches for a target value with a bit pattern that matches xxxx (i.e. random bits), then one may perform a non-linear binary search to find a matching target value in sorted inverse LUT **700**. If for example, the matching target value is $LUT[i_2]$, then one may access the correct corresponding message block i_2.

[0110] Referencing FIG. **8**, a chiplet **800** includes a public key cryptography engine **805** (PKC engine), a secure host **104**, a TX circuit **815** (a transmission circuit), and an RX circuit **828** (a receiving circuit). Chiplet **800** is communicably coupled via communication links **150** and **152** with a bus controller **146**, and via communication link **154** with a communication bus **156**. TX circuit **815** and RX circuit **828** are communicably linked with local host **104** via communication link **170**, and thus may receive commands, instructions, and data from local host **104**.

[0111] PKC engine **805** includes a public key encryption circuit PKC_E **858** which uses the public key of a receiver chiplet to encrypt the message, and a public key decryption circuit PKC_D **860** which uses the private key of the chiplet **800** to decrypt the ciphertext. PKC engine **805** is communicably coupled with bus controller **146** via communication link **148**. PKC engine **805** is also communicably linked with secure host **104** (e.g. one or more processing devices, such as for example, one or more CPU's).

[0112] TX circuit **815** includes a key manager **806**, a key generation function (sender) **808**, an Encryption Circuit **810**, a packet handler **818** for receiving transmissions from secure host **104** and a packet handler **820** for transmitting to bus controller **146** via communication link **150**.

[0113] Encryption Circuit **810** includes a dynamic substitution box in the form of LUT **812**, a dynamic keystream table in the form of KST **814**, and a counter in the form of ctr **816**. The KST **814** is optional. In some embodiments, target values that would be obtained from KST **814** are instead generated on the fly as needed, saving the need to generate and store the KST. The key generation function (sender) **808** is communicably linked for sending and receiving with TRNG **126** (a true random number generator) and for sending and receiving with PRNG **124** (a pseudo-random number generator). Encryption Circuit **810** is communicably linked for sending and receiving with CRC **122** (a CRC generator).

[0114] RX circuit **828** includes a key manager **830**, a key generation function (receiver) **832**, a Decryption Circuit **840**, a packet handler **844** for sending transmissions to secure host **104** and a packet handler **842** for receiving communications from bus controller **146** via communication link **152**. Decryption Circuit **840** includes a dynamic substitution box in the form of LUT **834**, a dynamic keystream table in the form of KST **836**, and a counter in the form of ctr **838**. In some embodiments, LUT **812** and LUT **834** share the same data, KST **814** and KST **836** share the same data, and ctr **816** and ctr **838** share the same data. The KST **836** is optional. In some embodiments, target values that would be obtained from KST **836** are instead generated on the fly as needed, saving the need to generate and store the KST. The key generation function (receiver) **832** is communicably linked for sending and receiving with PRNG **124** (a pseudo-random number generator). Decryption Circuit **840** is communicably linked for sending and receiving with CRC **122**.

[0115] A process is now described in which Chiplet **800** (a first chiplet) generates a session key K and transmits K to a second chiplet for use by the second chiplet in performing encryption. Consistent with some embodiments, the chiplet **800** may perform the following steps with the indicated components: (1) key generation function (sender) **808** computing a session key K consistent with method **900** of FIG. **9** (discussed below), (2) the key generation function (sender) **808** sending K to key manager **806** of the TX Circuit **815**, (3) the key manager **806** receiving K and further sending K to the Secure Host **104**, (4) Secure Host **104** configured for receiving K and further sending K to public key cryptography (PKC) engine **805** with a request for encryption operation on K and for transmission to a second chiplet, (5) PKC engine **805** receiving and then sending K along with the public key of the second chiplet to public key encryption module PKC_E **858**, (6) public key encryption module PKC_E **858** receiving K and public key of second chiplet, (7) public key encryption module PKC_E **858** encrypting K to obtain encrypted session key KEnc, the encryption including at least one or more operations that include at least some public key cryptography method, (8) public key encryption module PKC_E **858** further configured for sending KEnc to the PKC Engine **805**, and (9) PKC engine **805** receiving key KEnc and transmitting KEnc to the second chiplet via the communication link **148** to bus controller **146** and then via communication link **154** to the communication bus **156** for delivery to the second chiplet.

[0116] The second chiplet then continues the process with the following steps by the indicated components: (1) a PKC engine receiving KEnc from the first chiplet via the communication link via a bus controller the communication bus **156**, (2) the PKC engine sending key KEnc along with the private key of the second chiplet to a public key decryption module PKC_D, (3) the public key decryption module PKC_D receiving KEnc and the private key of second chiplet, (4) the public key decryption module PKC_D decrypting KEnc to obtain session key K, the decryption including at least one or more operations that include at least some public key cryptography method, (5) the public key decryption module PKC_D sending K to a PKC Engine of the second chiplet, (6) the PKC engine receiving K and then sending K to the Secure Host of the second chiplet, (7) the Secure Host receiving K and sending K to a key manager of the RX circuit of the second chiplet, (8) the key manager K and sending K to the key generation function (receiver) **832**, (9) the key generation function (receiver) receiving K from key manager of the RX Circuit of the second chiplet, and (10) key generation function (receiver) **832** computing the decryption key (LUT, KST, ctr) consistent with method **1000** of FIG. **10** (discussed below).

[0117] FIG. **9** and some subsequent drawings illustrate exemplary methods that are capable of being performed in one or more of the physical environments (e.g. chiplets) illustrated in other drawings. However, the exemplary methods are not limited to the disclosed physical environments and may be performed in a variety of other physical environments. In addition, although the exemplary methods have steps or operations that are illustrated as being performed in certain orders or sequences, it should be understood that at least some of the illustrated steps and orders may be performed in different orders or sequences or may be performed concurrently.

[0118] Referencing FIG. **9**, a method **900** of initializing a sender (e.g. TX circuit **815**) for encryption is illustrated. The input is a security parameter λ (lambda). The output is a session key (K), and the encryption key (LUT, KST, ctr) comprising of a dynamic substitution box (LUT), a dynamic keystream table (KST), and a counter (ctr). Method **900** will be referred to at times as the Sender's Key Generation Function ("K_Gen_Sender").

[0119] After a start operation **902**, control proceeds to operation **904** which inputs the security parameter λ. The λ controls various security matters such as the size of b and w from FIGS. **5-7** above. In addition to controlling message block size, the value b in some embodiments, also controls a nonce size. The nonce is important for security and is discussed further below.

[0120] Other matters set dependent on λ may include the length of CRC's (parameter len_crc), the size of the counter ctr (setting parameter len_ctr), the maximum size of a message (setting parameter max_mess_size), the maximum number of message blocks in a session (setting parameter max_blk_cnt), the refresh rate for the session keys (setting parameter ref_rate). Other start-up items include initializing the true random number generator TRNG **126**, initializing the pseudo-random number generators, such as PRNG **124**, and initializing the counter ctr (discussed below).

[0121] Control proceeds to operation **906** which computes random numbers r_0 and r_1. In some embodiments, operation **906** is performed with a TRNG **126**. The number of bits (e.g. the length) of r0 and r_1 is a security setting controlled by λ. Having been generated by, for example, TRNG **126**, r0 and r1 are true random numbers. In some alternative embodiments, r0 and r1 are generated with a pseudo-random number generator, such as for example PRNG **124**.

[0122] Control proceeds to operation **908** which computes a dynamic substitution box (LUT) using r0. In some embodiments, operation **908** is performed with a pseudo-random number generator which could be designated $PRNG_0$ and by using r0 as at least a portion of a seed for $PRNG_0$.

[0123] In some embodiments, r0 is used as at least a portion of a seed to compute the target values of LUT **500**. For example, LUT[M[0]] could be computed with just r0+M[0] as the seed for a pseudo-random number generator, such as for example, $PRNG_0$ **322**A with M[0] in this context being the numerical bits at M[0]. Then, LUT[M[1]] could be computed by seeding $PRNG_0$ **322**A with r0+M[1], LUT[M[2]] could be computed with r0+M[2] as the seed for $PRNG_0$ **322**A. Other target values LUT[M[i]] could be similarly computed. In another example, the target values LUT[M[i]] could be computed on a combination of the intermix of a bit **0** (to distinguish the use of $PRNG_0$ **322**A from $PRNG_1$ **324**A), value of message block M[i] and random string r0 as the seed for PRNG **124**. In another embodiment, the entire LUT table can be computed using $PRNG_0$ **322**A (or PRNG **124**, with an additional distinguisher 0 bit as input) with r0 as seed and specifying "$w*2^b$" bits as the length of output string. The generated random bit-string could be parsed and stored in the subsequent locations to populate the LUT.

[0124] Control proceeds to operation **910** which computes a KST using r1. In some embodiments, r1 is used as a portion of a seed for a different pseudo-random number generator which can be, for example, $PRNG_1$ **324**A. In some embodiments, the individual target values for KST are computed by seeding $PRNG_1$ with r1+x, where x is an index value. For example, KST[0] may be computed with the seed for $PRNG_1$ being r1+0. KST[1] may be computed with the seed for $PRNG_1$ being r1+1. KST[2] may be computed with the seed for $PRNG_1$ being r1+2. Other KST target values could be similarly computed. In another example, the target values KST[i] could be computed on a combination of the intermix of a bit **1** (to distinguish the use of $PRNG_1$ **324**A from $PRNG_0$ **322**A), index i and random string r1 as the seed for PRNG **124**.

[0125] Control proceeds to operation **912** which initializes counter ctr. In some embodiments, counter ctr is initialized at zero. In other embodiments, the counter ctr can be initialized to a random number that is dependent on one or more of the random numbers r0 and r1, generated using PRNG **124**, or any other mathematical function.

[0126] Control proceeds to operation **914** which computes a session key, designated K. In some embodiments, K=r0||r1, that is, r0 concatenated with r1. After this, in operation **916**, the Control proceeds to compute the encryption key, designated (LUT, KST, ctr), consisting of the dynamic substitution box (LUT), dynamic keystream table (KST) and the counter ctr. And in operation **918**, the following are output: (1) the session key K, and (2) the encryption key (LUT, KST, ctr) consisting of dynamic substitution table LUT, the dynamic keystream table KST, and counter ctr. Operation **920** is a stop operation.

[0127] Referencing FIG. **10**, a method **1000** of initializing a receiver (e.g. RX circuit **828**) for decryption is illustrated. The input is the security parameter λ and the session key K computed in method **900**. The output is the decryption key (LUT, KST, ctr) comprising of the dynamic substitution box (LUT), the dynamic keystream table (KST), and the counter ctr. Method **1000** will be referred to at times as the Receiver's Key Generation Function ("K_Gen_Receiver").

[0128] After start operation **1001**, control moves to operation **1002** which inputs the security parameter λ and session key K. The session key, K was computed in method **900** discussed above. The discussion of λ above regarding method **900** is fully applicable.

[0129] Control moves to operation **1004** which extracts random numbers r0 and r1 from K. The computation of r0 and r1 and how they are concatenated to form K is all discussed above relative to method **900**.

[0130] Control moves to operations **1006** and **1008** which, respectively, compute a dynamic substitution table (LUT) using r0 and computing a dynamic keystream table (KST) using r1. At least similar operations are discussed above relative to method **900** and that discussion is fully applicable here.

[0131] Control moves to operation **1010** which initializes a counter ctr. In some embodiments, ctr is initialized to zero. Some other methods of computation of ctr are discussed above relative to method **900**.

[0132] After this, in operation **1011**, the Control proceeds to compute the decryption key, designated (LUT, KST, ctr), consisting of the dynamic substitution box (LUT), dynamic keystream table (KST) and the counter ctr.

[0133] Control moves to operation **1012** which outputs the decryption key (LUT, KST, ctr). Control then moves to stop operation **1014**.

[0134] Referencing FIG. **11**, a method **1100** of encrypting a message is described. In discussing method **1100**, it is assumed that both of methods **900** and **1000** have been performed.

[0135] The input for method **1100** is the encryption key (LUT, KST, ctr), consisting of a dynamic substitution box (LUT), a dynamic keystream table (KST), and the counter ctr. Other inputs include some associated data A and a message M to encrypt. The output is a ciphertext with a "tag" and an updated counter ctr.

[0136] Of the above inputs, the LUT, KST, and ctr have been previously discussed. The associated data A refers to data that is not encrypted but that is incorporated into a CRC. The associated data A and its use is discussed further below.

[0137] The following discussion of FIG. **11** references an encryption algorithm A. Encryption algorithm embodies a particular embodiment within the scope of method **1100**. Those with skill in the art, once appraised of the principles discussed herein, will be aware of more alternatives to those stated below.

[0138] Encryption Algorithm A

Enc((LUT, KST, ctr), A, M)

1. If (ctr + len + 2 ≥ ref_rate) *
   a. Refresh Session Key (Execute Key Exchange Protocol.)
2. Compute nonce as N := KST[ctr] †.
3. Compute CRC on message M as T := CRC(N ∥ A ∥ M).
4. Parse M[1] ∥ M[2] ∥ ... ∥ M[len] := M ∥ T.
5. Initialize the temporary variable, temp := N ‡.
6. For i := 1,2, ... , len
   a. Parse $t_1 \| t_2 \| \ldots \| t_m$:= temp.
   b. Compute val := $t_1 \oplus t_2 \oplus \ldots \oplus t_m$ ♠.
   c. Compute C[i] := temp := LUT[M[i] ⊕ val] ⊕ KST[ctr + i] ✠.
7. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
8. Update counter ctr := ctr + len + 2.
9. Compute ciphertext C := C[1] ∥ C[2] ∥ ··· ∥ C[len].
10. Return C and ctr.

*: If counter is initialized as ctr := KST[0] mod 2^b, then, depending on the implementation, the condition will be:
   a. (blk_ctr + len + 2 ≥ ref_rate), or
   b. (ctr + len + 2 − KST[0] ≥ ref_rate).

†: Nonce can also be randomized as:
   a. Compute b := N & 0 × 01. (For the first value, N := KST[0])
   b. Compute idx := idx + 1. (For the first value, idx := 0)
   c. Compute N := $PRNG_{1-b}(r_b \| idx)$.

‡: Variable temp can also be computed as temp := LUT[N].

♠: For some Integer s, variable val can also be computed as:
   val := $t_1 \oplus (t_2 \ll s) \oplus \ldots \oplus (t_m \ll s(m-1))$

✠: C[i] can also be computed as:
   a. Compute temp := LUT[M[i] ⊕ val].
   b. Compute C[i] := temp ⊕ KST[ctr + i].

[0139] Again referencing FIG. **11**, after a start operation **1102**, control moves to operation **1104** which inputs the encryption key (LUT, KST, ctr), associated data A, and a message M to be encrypted.

[0140] Control moves to operation **1106** which determines if a block count exceeds a parameter ref_rate. Ref_rate is a refresh rate for session keys. In the embodiments of encryption algorithm A, it is determined if (ctr+len+2) are greater than or equal to the ref_rate. In this equation, len is the number of blocks to be encrypted and the number 2 is related to the computing of the nonce in process block **1110** and of a last block of ciphertext in process block **1124**, discussed below.

[0141] If the block count does not exceed the ref_rate, the control moves to operation **1110**, discussed below.

[0142] If the block count does exceed the ref_rate, then control moves to operation **1108** of refreshing the session key K. In some embodiments, this is performed by executing a key exchange protocol that includes at least:

[0143] a. Chiplet-1 (sender) executes the Sender's Key Generation Function (method **900**). This function, is described above relative to FIG. **9**. As noted above, the input is the security parameter λ and the outputs are a session key K, and an encryption key (LUT, KST, ctr).

[0144] b. Chiplet-1 sends the session key K to chiplet-2. In some embodiments, this step includes at least:

[0145] i. A public key of chiplet-2 is used to encrypt session key K.

[0146] ii. The encrypted session key KEnc is transmitted to Chiplet 2.

[0147] c. Chiplet-2 (receiver) uses its private key to decrypt the encrypted session key KEnc and thereby obtain the session key K.

[0148] d. Chiplet-2 executes the Receiver's Key Generation Function (method **1000**). This function is described above relative to FIG. **10**. As noted above, the inputs are the session key K and the security parameter λ. The output is the decryption key (LUT, KST, ctr).

[0149] It is important to regularly execute the key exchange protocol because XOR operations produce identical output for a large set of input values. For example: $0\oplus3=3$, $1\oplus2=3$, $4\oplus7=3$, $5\oplus6=3$ and so on. This is called collision. The probability of collision increases with an increase in the number of input sets. For an XOR with b-bit inputs, after $2^{b/2}$ input sets, the probability of collision becomes significant. To avoid collision, the LUT and KST must be modified. Therefore, after a specified number of encryptions of message blocks, as defined by the parameter ref_rate, the session key is refreshed by invoking the key exchange protocol. The value of ref_rate, in some embodiments, is less than $2^{b/2}$. In some further embodiments, ref_rate is $2^{(b/2-1)}$.

[0150] Control moves to operation **1110** which initializes a nonce N. In some embodiments, the value b, set with security parameter λ, determines the length of nonce N. Generally, a longer length of nonce N is associated with increased security relative to a shorter length of Nonce N. Consistent with some embodiments, in encryption Algorithm A, the initialization of nonce N may be performed by setting Nonce N equal to KST[ctr], where ctr is a counter initialized in operation **912**. As discussed relative to operation **912**, in some embodiments, ctr is initialized as zero. In those embodiments, Nonce N is initialized to KST[0], that is, the first target value in the first row of the KST.

[0151] Nonce N has a high degree of randomness because it is initialized as KST[0] and the KST is, in some embodiments, created using a random number r1 computed with TRNG. In those embodiments, r1 is a true random number. Nonce N therefore has a high degree of randomness. This high degree of randomness of nonce N helps prevent nonce forgery and nonce-reuse attacks.

[0152] Control moves to operation **1112** which computes a tag T on N||A||M, where N is nonce N, A is associated data, and M is a message to be encrypted. In some embodiments, T is a CRC. In those embodiments, we have T=CRC (N||A||M). After the tag T is computed, it is concatenated with the message M to be encrypted, that is M||T.

[0153] Control moves to operation **1114** which parses M||T into message blocks, such as M[1], M[2], M[3], . . . , M[len], where len is the total number of blocks. The size of the blocks in bits is governed by the value b, discussed above.

[0154] Control moves to operation **1116** which initializes a counter variable i to 1. In some embodiments, a temp variable is initialized to the value of nonce N.

[0155] A loop is executed that includes the following operations:

[0156] a. Operation **1118** determines if the variable i is less than or equal to len, the number of message blocks to be encrypted. If i is greater than len, then the loop is exited and control moves to operation **1124** below.

[0157] b. Operation **1120** computes the ciphertext for M[i], which is C[i]. Referencing encryption algorithm A, in some specific embodiments, computing C[i] includes at least:

[0158] i. Parse t1||t2|| . . . ||tm:=temp, where, in some embodiments, m is the number of b-bit blocks in temp and computed as "m=w/b". That is, temp is parsed into w/b blocks of length b bits each. It will be recalled that temp was initialized to the value of Nonce N, above, which is w bits in length. This value of temp is for the first time through the loop. As indicated below, for subsequent loops, temp is set to the value of C[i], thereby keeping some continuity between blocks of the ciphertext.

[0159] ii. Compute val:=t1⊕t2⊕ . . . ⊕tm, where ⊕ is the symbol for a bitwise XOR operation. This equation XOR's the w/b blocks of b bits of temp together and stores the result in the variable val.

[0160] iii. Compute C[i]:=temp:=LUT[M[i]⊕val]⊕KST[ctr+i]. Here, in this step, C[i] and temp are both set equal to the result of the mathematical expression on the right. Turning to the mathematical expression, in a left subexpression M[i] and val are XOR'd and the result is the key used in the first column of the LUT to obtain its corresponding target value in the second column of the LUT. This target value may be referred to as a first target value. In a right subexpression, the value of the counter ctr is added to the variable i, and the result is the key used in the first column of the KST to obtain its corresponding target value in the second column of the KST. This target value may be referred to as the second target value. Then, the right expression XOR's first and the second target values to obtain both the ciphertext C[i] and the new value for temp.

[0161] c. Operation **1122** updates i incrementing by one. Control then returns to operation **1118** and the loop then repeats until in operation **1118**, i is greater than len. When i is greater than len, the loop terminates and control moves to operation **1124**.

[0162] Operation **1124** computes the value for the last block of ciphertext C[len]. Referencing encryption algorithm A, in some specific embodiments, computing C[len] includes at least computing C[len]:=C[len]⊕KST[ctr+len+1]. Turning to this equation and moving from the left, the last ciphertext block C[len] is equal to a mathematical expression on the right. Moving to the mathematical expression, the left subexpression C[len] is the ciphertext for the last block computed as explained regarding operation **1120**. The right subexpression includes looking up a target value in KST wherein the key is (ctr+len+1), that is the sum of current value of the counter ctr, the value len, and the number 1. The resulting KST target value is XOR'd with the C[len] to arrive at the final value for C[len]. This operation prevents the length-extension attacks on the cryptosystem.

[0163] Control moves to operation **1126** which updates the counter ctr. Referencing encryption algorithm A, in some specific embodiments, updating ctr includes ctr:=ctr+len+2. This updates ctr by adding the number of message blocks encrypted, len. And by adding the number two, which accounts for the additional processing of the nonce in operation **1110** and the last block in operation **1124**, we ensure that no random number block is repeated.

[0164] In further explanation for the updating of ctr by let+2, it is noted that the first block KST[ctr] is consumed in assigning a fresh new random number for Nonce, operation **1110**. The next len blocks—KST[ctr+1] to KST[ctr+len]—are consumed in the encryption of message blocks, operation **1120**. The last block KST[ctr+len+1] is consumed in the extra encryption of the Last ciphertext block C[len]. So, to avoid repetition of the value, ctr is updated by len+2.

[0165] Control moves to operation **1128** which calculates the ciphertext by concatenating the ciphertext blocks C[1], C[2], . . . C[len].

[0166] Control then moves to operation **1130** which outputs C and ctr as the outputs of the Encryption Circuit, method **1100**. Control then moves to Stop operation **1132**.

[0167] The above method **1100** is subject to a variety of implementations. For example, in some implementations it is desired to disable one of more of authentication or encryption. In the below encryption algorithm B, FlagA enables or disables authentication and FlagE enables or disables encryption. Encryption algorithm B is as follows:

[0168] Encryption Algorithm B

Enc((LUT, KST, ctr), A, M)

---

1. If (ctr + len + 2 ≥ ref_rate) *
   a. Refresh Session Key (Execute Key Exchange Protocol.)
2. Compute nonce as N := KST[ctr] †.
3. If ($Flag_A$ = = 1)
   a. Compute CRC on message M as T := CRC (N ∥ A ∥ M).
4. Else, Initialize T := ϵ.
5. If ($Flag_E$ = = 1)
   a. Parse M[1] ∥ M[2] ∥ ... ∥ M[len] := M ∥ T.
6. Else, Parse M[1] ∥ M[2] ∥ ··· ∥ M[len] := T.
7. Initialize the temporary variable, temp := N ‡.
8. For i := 1,2, ... , len
   a. Parse $t_1 \| t_2 \| \ldots \| t_m$:= temp.
   b. Compute val := $t_1 \oplus t_2 \oplus \ldots \oplus t_m$ ♠
   c. Compute C[i] := temp := LUT [M[i] ⊕ val] ⊕ KST[ctr + i] ✠.
9. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
10. Update counter ctr := ctr + len + 2.
11. If ($Flag_E$ = = 1)
    a. Compute ciphertext C := C[1] ∥ C[2] ∥ ... ∥ C[len].
12. Else, Compute ciphertext C := M ∥ C[1] ∥ C[2] ∥ ... ∥ C[len].
13. Return C and ctr.

*: If counter is initialized as ctr := KST[0] mod 2^b, then, depending on the implementation, the condition will be:
   a. (blk_ctr + len + 2 ≥ ref_rate), or
   b. (ctr + len + 2 − KST[0] ≥ ref_rate).

†: Nonce can also be randomized as:
   a. Compute b := N & 0 × 01. (For the first value, N := KST[0])
   b. Compute idx := idx + 1. (For the first value, idx := 0)
   c. Compute N := $PRNG_{1-b}(r_b \| idx)$.

‡: Variable temp can also be computed as temp := LUT[N].

♠ For some Integer s, variable val can also be computed as:
   val := $t_1 \oplus (t_2 \ll s) \oplus \ldots \oplus (t_m \ll s(m-1))$

✠: C[i] can also be computed as:
   a. Compute temp := LUT[M[i] ⊕ val].
   b. Compute C[i] := temp ⊕ KST[ctr + i].

[0169] Referencing FIG. **12**, decryption method **1200** decrypts ciphertext C created with method **1100**. Method **1200** includes as inputs the decryption key (LUT, KST, ctr), associated data A, and the ciphertext C output by method **1100**. The outputs are the decrypted message M and an updated counter ctr. In discussing method **1200**, it is assumed that methods **900** and **1100** have been performed at a first chiplet, chiplet-1, that method **1000** has been performed at a second chiplet, chiplet-2, and that chiplet-1 has transmitted ciphertext C to chiplet-2. Decryption method **1200** is performed at chiplet-2.

[0170] The discussion of FIG. **12** references decryption algorithm C. Decryption algorithm C embodies specific embodiments within the scope of method **1200** of FIG. **12**. Those with skill in the art, once appraised of the principles discussed herein, will be aware of more alternatives to those stated below.

[0171] Decryption Algorithm C

Dec((LUT, KST, ctr), A, C)

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1. Compute nonce as N := KST[ctr] †.
2. Parse C[1] ∥ C[2] ∥ ... ∥ C[len] := C.
3. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
4. Initialize the temporary variable, temp := N ‡.
5. For i := 1,2, ··· , len
   a. Parse $t_1 \| t_2 \| \ldots \| t_m$:= temp.
   b. Compute val := $t_1 \oplus t_2 \oplus \ldots \oplus t_m$♠ .
   c. Compute temp := C[i] ✠ .
   d. Compute M[i] := LUT^{-1}[C[i] ⊕ KST[ctr + i] ⊕ val ✠ .
6. Compute message M ∥ T := M[1] ∥ M[2] ∥ ··· ∥ M[len].
7. Compute CRC on message M as T' := CRC(N ∥ A ∥ M).
8. If (T = = T')
   a. Update counter ctr := ctr + len + 2.
   b. Return M and ctr.
9. Else
   a. Return Error.

†: Nonce can also be randomized as:
   a. Compute b := N & 0 × 01. (For the first value, N := KST[0])
   b. Compute idx := idx + 1. (For the first value, idx := 0)
   c. Compute N := $PRNG_{1-b}(r_b \| idx)$.

‡: Variable temp can also be computed as temp := LUT[N].

♠: For some Integer s, variable val can also be computed as:
   val := $t_1 \oplus (t_2 \ll s) \oplus \ldots \oplus (t_m \ll s(m-1))$

✠: M[i] can also be computed as:
   a. Compute temp := C[i] ⊕ KST[ctr + i].
   b. Compute M[i] := LUT^{-1}[temp] ⊕ val.

[0172] Again referencing method **1200**, after a start operation **1202**, control moves to operation **1204** which receives as input the decryption key (LUT, KST, ctr), associated data A, and the ciphertext C to be decrypted.

[0173] Control moves to **1206** which initializes nonce N. This operation **1206** is unchanged from operation **1110** of method **1100**. Reference is made to the discussion of operation **1110**.

[0174] Control moves to operation **1208** which parses C into ciphertext blocks C[1], C[2], . . . , C[len], where len is the total number of ciphertext blocks. The parameter w, discussed above, governs the size of the ciphertext blocks.

[0175] Control moves to operation **1210** which processes the last ciphertext block C[len]. In some specific embodiments decryption Algorithm C uses the following equation C[len]:=C[len]⊕KST[ctr+len+1]. The same XOR operation with the same operands was performed in operation **1124** of method **1100**. Performing an XOR operation twice results in the original values as they existed before the first XOR. Thus, operation **1210** of method **1200** reverses the processing of operation **1124**. The result is that C[len] is the last ciphertext block as it existed prior to the processing of operation **1124**.

[0176] Control moves to operation **1212** which initializes a counter variable i to 1. In some embodiments, operation **1212** also initializes a "temp" variable to the value of nonce N.

[0177] A loop is executed that includes the following operations:

[0178] a. Operation **1214** determines if the variable i is less than or equal to the parameter len, the number of ciphertext blocks to be decrypted. If i is greater than len, then the loop is exited and control moves to operation **1220** below.

[0179] b. Operation **1216** computes message block M[i] by decrypting ciphertext C[i]. Referencing decryption algorithm C, in some specific embodiments, computing M[i] includes at least:

[0180] i. Parse t1||t2|| . . . ||tm:=temp, where, in some embodiments, m is the number of b-bit blocks in temp and computed as "m=w/b". Temp is parsed into w/b blocks of length b bits each. Operation **1212** initialized temp to the value of Nonce N, which is w bits in length, for the first time through the loop. For subsequent loops, step iii (below) sets temp is set to the value of C[i].

[0181] ii. Compute val:=t1⊕t2⊕ . . . ⊕tm. That is, the b-bit w/b blocks of temp are XOR'd together and the result is stored in the variable val.

[0182] iii. Assign Temp:=C[i]. Temp is set to equal C[i] for second and subsequent iterations of the loop.

[0183] iv. Compute M[i]:=LUT^{-1}[C[i]⊕KST[ctr+i]]⊕val. This equation sets M[i] as equal to the result of the mathematical expression on the right. Turning to the mathematical expression, in a left subexpression, LUT^{-1}[C[i]⊕KST[ctr+i]], the LUT^{-1} refers to an inverse LUT (i.e. LUT^{-1}) as described relative to FIG. **7**. As discussed above, for LUT^{-1} the message blocks in the first column are the target values and the corresponding blocks of random or pseudo-random bits are the keys. That is the reverse of normal LUT operation. Thus key for the LUT^{-1} is [C[i]⊕KST[ctr+i]]. That key is simplified by XOR'ing C[i] with the target value obtained by using ctr+i as the key to the KST, ctr+i being the current value of the counter ctr plus the value of counter variable i. The value obtained via the left subexpression is then XOR'd with val.

[0184] c. Operation **1218** updates i by incrementing i by one. Control then returns to operation **1214** and the loop then repeats until in operation **1214**, i is greater than len. When i is greater than len, the loop terminates and control moves to operation **1220**.

[0185] Once the loop terminates, control moves to operation **1220**, which concatenates M[1], M[2] . . . M[len] to obtain M||T, which was originally computed in operation **1112** of method **1100**.

[0186] Control moves to operation **1222** which computes a tag T'. In embodiments in which T'**1***s* a CRC, operation **1222** computes CRC(N||A||M).

[0187] Control moves to operation **1224** which determines if T==T'. That is, operation **1224** determines if the tag T that was originally computed in operation **1112** of method **1100** and is received after decryption of ciphertext C in operation **1220**, is equal to tag T' computed in operation **1222**.

[0188] If no, control moves to operation **1228** which outputs an error. Control then moves to stop operation **1232**.

[0189] If yes, then control moves to operation **1226** which updates the counter ctr. Referencing decryption algorithm C, in some embodiments, the counter is updated by setting ctr:=ctr+len+2. Thus, the value of ctr at chiplet-2 after method **1200** is the same as the value ctr at chiplet-1 after method **1100**. Control then moves to operation **1230** which outputs the message M and updated counter ctr as the output of method **1200**. Control then moves to stop operation **1232**.

[0190] The above method **1200** is an exemplary embodiment. Various implementations are possible. For example, in another implementation, flags are provided to enable/disable authentication and to enable/disable encryption. This implementation is set forth as decryption algorithm D. In this algorithm, FlagA enables/disables authentication and FlagE enables/disables encryption.

[0191] Decryption Algorithm D

Dec((LUT, KST, ctr), A, C)

1. Compute nonce as N := KST[ctr] †.
2. If ($Flag_E$ = = 1)
   a. Parse C[1] ‖ C[2] ‖ ... ‖ C[len] := C.
3. Else, If ($Flag_A$ = = 1)
   i. Parse M ‖ C[1] ‖ C[2] ‖ ... ‖ C[len] := C.
4. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
5. Initialize the temporary variable, temp := N ‡.
6. For i := 1,2, ··· , len
   a. Parse t_1 ‖ t_2 ‖ ... ‖ t_m := temp.
   b. Compute val := t_1 ⊕ t_2 ⊕ ... ⊕ t_m♠ .
   c. Compute temp := C[i]✠ .
   d. Compute M[i] := LUT^{-1}[C[i] ⊕ KST[ctr + i]] ⊕ val✠ .
7. If ($Flag_A$ = = 1)
   a. If ($Flag_E$ = = 1)
      i. Compute message M ‖ T := M[1] ‖ M[2] ‖ ... ‖ M[len].
   b. Else, Compute T := M[1] ‖ M[2] ‖ ... ‖ M[len].
   c. Compute CRC on message M as T' := CRC(N ‖ A ‖ M).
   d. If(T = = T')
      i. Update counter ctr := ctr + len + 2.
      ii. Return M and ctr.
   e. Else, Return Error.
8. Else
   a. If ($Flag_E$ = = 1)
      i. Compute message M := M[1] ‖ M[2] ‖ ... ‖ M[len].
   b. Update counter ctr := ctr + len + 2.
   c. Return M and ctr.

†: Nonce can also be randomized as:
   d. Compute b := N & 0 × 01. (For the first value, N := KST[0])
   e. Compute idx := idx + 1. (For the first value, idx := 0)
   f. Compute N := $PRNG_{1-b}(r_b$ ‖ idx).

‡: Variable temp can also be computed as temp := LUT[N].

♠: For some Integer s, variable val can also be computed as:
   val := t_1 ⊕ (t_2 << s) ⊕ ... ⊕ (t_m << s(m − 1))

✠: M[i] can also be computed as:
   c. Compute temp := C[i] ⊕ KST[ctr + i].
   d. Compute M[i] := LUT^{-1}[temp] ⊕ val.

[0192] Various example modes of communication between a chiplet-1 (e.g. a first chiplet) and a chiplet-2 (e.g. a second chiplet) are now discussed with reference to exemplary sequences. A sequence of communication between chiplet-1 and chiplet-2 may include multiple messages. Usually, communications are bi-directional. If both of the chiplets may send data only sequentially, one-after-the-other, then the communication is half-duplex. If both of the chiplets may send data concurrently, then the communication is full-duplex.

[0193] For simplicity, in some exemplary sequences described below only one chiplet (for example chiplet-1) is sending messages to the other chiplet (for example chiplet-2). However, this feature is not intended to be limiting. Those skilled in the art will recognize that the exemplary sequences described can be extended to bi-directional communication without undue experimentation.

[0194] In the example communication sequences described below, the messages M_1, M_2, . . . M_i (of lengths n_1, n_2, . . . n_i) are encrypted and sent by chiplet-1 to chiplet-2 in sequence. The counter variable ctr is synchronized with the following procedures:

[0195] a. The variable ctr is initialized to identical value in both chiplet-1 and chiplet-2.

[0196] b. The ctr is updated on the sender side (chiplet-1) just after encryption of a message.

[0197] c. The ctr is updated on the receiver side (chiplet-2) only after successful decryption and verification of received ciphertext. (The ciphertext is resent if verification fails).

[0198] Each of the example communication sequences shown below begins with chiplet-1 and chiplet-2 authenticating themselves to each other. There are a variety of techniques for chiplets authenticating themselves to one another. Some authentication techniques use the existing Public Key Infrastructure (PKI) with the Digital Signature Algorithm (DSA), others deploy a blockchain-based mechanism. A discussion on chiplet authentication techniques is beyond the scope of this document.

[0199] Referencing FIG. **13**, communication sequence **1300** begins with chiplet authentication **1302** between chiplet-1 **1312** and chiplet-2 **1314**. A key exchange **1304** is then performed between chiplet-1 and chiplet-2. In some embodiments, the key exchange **1304** is performed by executing a Key Exchange Protocol consistent with methods **900** and **1000** of FIGS. **9** and **10**, respectively.

[0200] The communication sequence **1300** proceeds to step 1 with chiplet-1 encrypting M_1 by computing ciphertext C_1. In some embodiments, chiplet-1 performs the encryption by executing an encryption function such as method **1100**.

[0201] In step 2, chiplet-1 transmits the ciphertext C_1 via transmission **1306** to chiplet-2. In step 3, chiplet-2 decrypts ciphertext C_1 and computes plaintext M_1. In some embodiments, chiplet-2 performs the decryption by executing a decryption function such as method **1200**.

[0202] The communication sequence **1300** continues with chiplet-1, in step 4, encrypting a second message M_2 by computing ciphertext C_2. In step 5, chiplet-1 transmits ciphertext C_2 to chiplet-2 via transmission **1308**. In step 6, chiplet-2 decrypts ciphertext C_2 and computes message M_2.

[0203] In step 7, chiplet-1 encrypts message M_i by computing ciphertext C_i. In step 8 chiplet-1 transmits ciphertext C_i to chiplet-2 via transmission **1310**. In step 9, chiplet-2 decrypts C_i to compute M_i.

[0204] The discussion below proceeds to discuss a chiplet and a communication sequence for unoptimized basic half-duplex mode of communication. Basic half-duplex mode of communication is a known mode of communication that is incorporated into embodiments herein, as discussed below.

[0205] In basic half-duplex mode of communication only one chiplet at a time (e.g. chiplet-1) may transmit data. The other chiplet (e.g. chiplet-2) must wait to transmit until the data transmitted from chiplet-1 is all received and decrypted successfully. The value of a counter ctr is the same for each chiplet and is the same for both transmitting and receiving. There are four types of control signals which allow smooth transmission of data in the transmission channel or bus:

[0206] a. The SND signal: A chiplet sends the SND signal when the chiplet seeks to send data. When a chiplet receives the SND signal, it stops all its transmission-related activities and begins to wait for the data from the other chiplet. At the receiver's side, the waiting period is predefined. If the receiver does not receive any data within the predefined period, the SND signal is dropped. If the SND signal is dropped, the sender then needs to re-send the SND signal before starting to send data.

[0207] b. The ACK signal: A chiplet sends ACK when the chiplet has successfully decrypted, and verified the transmitted data. When a chiplet receives an ACK signal, it is confirmation that its previously sent data has been decrypted and verified successfully. If a chiplet has not received an ACK signal within a predefined period of time and if the SND signal has not expired, the chiplet resends the data. If a chiplet has not received an ACK signal within the predefined period of time and if the SND signal has expired, then the chiplet will resend the SND signal and then resend the data.

[0208] c. The NACK signal: A chiplet sends the NACK signal when the chiplet has received the data but has not successfully decrypted and verified the data. When a chiplet receives the NACK signal, it resends the data. The NACK signal is evidence of error at a higher-layer of a network stack or of an attack by an adversary. If the number of NACK signals exceeds a threshold, a session may be terminated and a new session be established.

[0209] d. The SND-ACK signal: This signal is a combination of the SND and ACK signals. A chiplet sends the SND-ACK signal when the chiplet has successfully decrypted and verified data and then seeks to send data. When a chiplet receives an SND-ACK signal, it is confirmed that its previously sent data has been successfully decrypted and verified and that the chiplet must wait for the other chiplet to send data. The SND-ACK signal provides a fair opportunity for a receiving chiplet to send data. It also ensures that one chiplet does not hold or occupy a communication channel for too long.

[0210] Referencing FIG. **14**, a chiplet **1400** is configured for encryption and decryption, for example via methods **1100** and **1200**, and for basic (e.g. unoptimized) half-duplex mode of communication. Except where discussed below, chiplet **1400** is at least similar to chiplet **800**. Elements present in chiplet **800** that are not changed in chiplet **1400** are not further discussed. Instead, for these unchanged elements, this document relies on the discussion relative to chiplet **800**. The same applies below regarding drawings of additional chiplets (i.e. chiplets **1600**, **1800**, **2000**, **2100**, **2200**). For each of these additional chiplets, only new elements or changed elements are discussed. And reliance is placed on previous discussions regarding unchanged elements of chiplets.

[0211] Chiplet **1400** includes a secure host **1404** that includes a basic half-duplex mode circuit **1457** that configures local host **1404** for issuing instructions, commands, and data for causing chiplet **1400** to communicate via basic half-duplex mode of communication. In some embodiments basic half-duplex mode circuit **1457** is a memory bearing executable instructions for causing chiplet **1400** to communicate via basic half-duplex mode. In some other embodiments, basic half-duplex mode circuit **1457** is hard-wired logic. And in yet some other embodiments, basic half-duplex mode circuit **1457** includes both a memory with executable instructions and hard-wired logic.

[0212] The chiplet **1400** includes a TX circuit **1415** (a transmission circuit). TX circuit **1415** includes Encryption Circuit **1410**. In contrast to the chiplet **800** of FIG. **8**, Encryption Circuit **1410** does not include, but is instead communicably linked with an LUT **1412**, a KST **1414**, a counter in the form of ctr **1416**, and a CRC **122** (a CRC generator). Access to the foregoing elements is shared between Encryption Circuit **1410** and Decryption Circuit **1440** (discussed below).

[0213] Chiplet **1400** includes a RX circuit **1428** (a receiving circuit). RX circuit **1428** includes a Decryption Circuit **1440**. In contrast to Decryption Circuit **840** of FIG. **8**, Decryption Circuit **1440** does not include but is instead communicably linked with the LUT **1412**, the KST **1414**, the counter ctr **1416**, and the CRC **122**. The foregoing elements are shared between Decryption Circuit **1440** and Encryption Circuit **1410**. A shared LUT, KST and ctr offers the advantage of saving a huge memory space, which otherwise would be double, as shown in FIG. **8**. The shared memory could be, for example, one or more SRAM's (not shown).

[0214] Referencing FIG. **15**, a communication sequence **1500** illustrates an example of basic half-duplex mode of communication. Time proceeds as shown by timeline **1526**. Sequence **1500** begins with chiplet authentication **1502** between chiplet-1 (**1522**) and chiplet-2 (**1524**). After chiplet authentication, chiplet-1 and chiplet-2 perform a key exchange **1504**.

[0215] At step 1, chiplet-1 generates a message M_1 and checks whether chiplet-2 has sent an SND signal. After determining that chiplet-2 has not sent an SND signal, at step 2, chiplet-1 sends an SND signal to chiplet-2 via transmission **1506**.

[0216] At step 3, chiplet-2 is waiting for M_1 and also generates a message M'_1.

[0217] At step 4, chiplet-1 completes the encryption of M_1 by computing ciphertext C_1. In some embodiments, chiplet-1 performs the encryption by executing an encryption function such as method **1100** of FIG. **11**. In step 5, chiplet-1 transmits C_1 to chiplet-2 via transmission **1508**.

[0218] In step 6, chiplet-2 decrypts C_1 and thereby generates M_1. In some embodiments, chiplet-2 performs the decryption by executing a decryption function such as method **1200** of FIG. **12**.

[0219] In step 7, chiplet-2 generates a message M'_2. And in step 8, chiplet-2 sends an SND-ACK signal to chiplet-1 via transmission **1510**. This signal confirms decryption and verification of M_1 and places chiplet-1 in a waiting mode. Chiplet-1 is waiting for M'_1.

[0220] In step 9, chiplet-2 completes the encryption of M'_1 by computing ciphertext C'_1 and in step 10 sends C'_1 to chiplet-1 via transmission **1512**.

[0221] At step 11, chiplet-1 decrypts C'_1 and thereby computes M'_1. At step 12, Chiplet-1 sends an ACK signal to chiplet-2 via transmission **1514**. This signal confirms decryption and verification of M'_1 and also signals to chiplet-2 that chiplet-1 does not have a message to send.

[0222] At step 13, chiplet-2 sends an SND signal to chiplet-1 via transmission **1516**. Chiplet-1 begins waiting for M'_2. At step 14, chiplet-2 encrypts M'_2 by computing the ciphertext C'_2. In step 15, chiplet-2 sends C'_2 to chiplet-1 via transmission **1518**.

[0223] In step 16, chiplet-1 decrypts C'_2 to compute M'_2. At step 17, chiplet-1, having successfully decrypted and verified M'_2 sends an ACK signal via transmission **1520**. The ACK signal confirms successful decryption and verification of M'_2 and also signals that chiplet-1 does not have a message to send.

[0224] Advantages of the basic half-duplex mode of communication are the need to store only one counter and the simplicity of Chiplet **1400** of FIG. **14**. Disadvantages include low channel utilization and secure time-stamping of the control signals is required to resolve conflicts.

[0225] The discussion below proceeds to discuss a chiplet and a communication sequence for unoptimized full-duplex mode of communication. Full-duplex mode of communication is a known mode of communication that is incorporated into embodiments herein, as discussed below.

[0226] In full-duplex mode of communication both chiplets can send data simultaneously. The encryption/decryption process and the transmission of data are not dependent on another chiplet. A chiplet has two counters, ctr and ctr': one for sending messages and one for receiving messages. The session key K is the same for both sending and receiving.

[0227] Referencing FIG. **16**, a chiplet **1600** is configured for encryption and decryption, for example via methods **1100** and **1200**, and for full-duplex mode of communication. Unlike chiplet **1400** of FIG. **14**, this chiplet **1600** has a counter ctr **1616** for transmission and another counter ctr' **1638** for receiving.

[0228] Chiplet **1600** includes a secure host **1604** that includes a full-duplex mode circuit **1657** that configures local host **1604** for issuing instructions, commands, and data for causing chiplet **1600** to communicate via full-duplex mode of communication. In some embodiments, full-duplex mode circuit **1657** is a memory bearing executable instructions for causing chiplet **1600** to communicate via full-duplex mode. In some other embodiments, full-duplex mode circuit **1657** is hard-wired logic. And in yet some other embodiments, full-duplex mode circuit **1657** includes both a memory with executable instructions and hard-wired logic.

[0229] The chiplet **1600** includes a TX circuit **1615** (a transmission circuit). TX circuit **1615** includes encryption circuit **1610** which includes a counter ctr **1616** dedicated to the TX circuit **1615**. That is, ctr **1616** is not shared with RX circuit **1628** (below).

[0230] Chiplet **1600** includes an RX circuit **1628** (a receiving circuit). RX circuit **1628** includes decryption circuit **1640** which includes a counter ctr' **1638** dedicated to the RX circuit **1628**. That is, ctr' **1638** is not shared with TX circuit **1615**. The separate counters ctr **1616** and ctr' **1638** at least partially configure chiplet **1600** for full-duplex mode.

[0231] Referencing FIG. **17**, a communication sequence **1700** illustrates full-duplex mode of communication between chiplet-1 (**1718**) and chiplet-2 (**1720**). In some embodiments, chiplet-1 is chiplet **1600** above and stores: a) A session key K that equals r0||r1, b) an LUT generated with random number r0, c) a counter ctr for sending data, and d) a counter ctr' for receiving data. Although FIG. **16** shows KST **1414** shared by encryption circuit **1610** and decryption circuit **1640**, this is optional. A KST need not be stored because values from a KST can be computed on the fly.

[0232] In those embodiments, chiplet-2 stores a) the same session key K that equals r0||r1, b) the same LUT generated with random number r0, c) the counter ctr but for receiving data, and d) the counter ctr' but for sending data. Thus, in chiplet-2 the role of the counters is reversed compared to their role in chiplet-1. A KST need not be stored because values from a KST can be computed on the fly.

[0233] The number of control signals for full-duplex mode is simplified and includes two control signals:

[0234] a. The ACK signal: A chiplet sends the ACK signal to indicate that it has successfully decrypted and verified the transmitted data. When a chiplet receives the ACK signal, it is confirmed that its previously sent data has been decrypted and verified successfully. If a chiplet does not receive an ACK signal within a predefined period of time after sending data, the data is resent.

[0235] b. The NACK signal: A chiplet sends the NACK signal when the chiplet has received the data but has not successfully decrypted and verified the data. When a chiplet receives the NACK signal, it resends the data. The NACK signal is evidence of error at a higher-layer of a network stack or of an attack by an adversary. If the number of NACK signals exceeds a threshold, a session may be terminated and a new session be established.

[0236] The direction of time for communication sequence **1700** is shown by timeline **1722**. Communication sequence **1700** begins with chiplet authentication **1702** between chiplet-1 (**1718**) and chiplet-2 (**1720**). After chiplet authentication, chiplet-1 and chiplet-2 perform a key exchange **1704**. In some embodiments, chiplet-1 and chiplet-2 perform the key exchange by executing a Key Exchange Protocol consistent with methods **900** and **1000** of FIGS. **9** and **10**, respectively.

[0237] At step 1, chiplet-1 generates a message M_1. Meanwhile, at step 2, chiplet-2 generates message M'_1.

[0238] At step 3, chiplet-1 encrypts message M_1 by computing ciphertext C_1. In parallel, at step 4, chiplet-2 encrypts message M'_1 by computing ciphertext C'_1.

[0239] At step 5, chiplet-1 transmits C_1 to chiplet-2 via transmission **1706**. At step 6, chiplet-2 decrypts C_1 to obtain M_1. At step 7, chiplet-2 transmits C'_1 to chiplet-1 via transmission **1708**.

[0240] At step 8, chiplet-1 decrypts C'_1 to compute M'_1. At step 9, chiplet-2 generates M'_2, but chiplet-2 has not received an ACK for M'_1 so it awaits taking action on M'_2. At step 10 chiplet-2 sends an ACK signal to chiplet-1 via transmission **1710**, signaling that chiplet-2 has decrypted and verified M_1. At step 11, chiplet-1 sends an ACK signal to chiplet-2 via transmission **1712**, signaling that chiplet-1 has decrypted and verified M'_1.

[0241] At step 12 chiplet-2 encrypts message M'_2 by computing ciphertext C'_2. And at step 13 chiplet-2 transmits C'_2 to chiplet-1 via transmission **1714**.

[0242] At step 14 chiplet-1 decrypts C'_2 to compute M'_2 and at step 15 chiplet-1 sends an ACK signal to chiplet-2 via transmission **1716**, signaling that chiplet-2 has decrypted and verified M'_2.

[0243] The discussion below proceeds to discuss a chiplet and a communication sequence for a new communication mode, no-delay half-duplex mode. In no-delay half-duplex mode, a chiplet may, while waiting for a message after receiving an SND signal, encrypt its own message using a different counter. And while a chiplet is decrypting received data, it can transmit its own encrypted data over the channel, improving the channel utilization.

[0244] Referencing FIG. **18**, a chiplet **1800** is configured for encryption and decryption, for example via methods **1100** and **1200**, and for communication via no-delay half-duplex mode. The no-delay half-duplex mode is enabled at least in part by no-delay half duplex mode circuit **1857** and by having two counters, a counter ctr **1616** for transmission and another counter ctr' **1638** for receiving.

[0245] Chiplet **1800** includes a secure host **1804** that includes a no-delay half-duplex mode circuit **1857** that configures local host **1804** for issuing instructions, commands, and data for causing chiplet **1800** to communicate via no-delay half-duplex mode of communication. In some embodiments, no-delay half-duplex mode circuit **1857** is a memory bearing executable instructions for causing chiplet **1800** to communicate via no-delay half-duplex mode. In some other embodiments, no-delay half-duplex mode circuit **1857** is hard-wired logic. And in yet some other embodiments, no-delay half-duplex mode circuit **1857** includes both a memory with executable instructions and hard-wired logic.

[0246] As described above regarding chiplet **1600**, Chiplet **1800** includes a TX circuit **1615** with Encryption Circuit **1610** which includes a counter ctr **1616** dedicated to the TX circuit **1615**. And, as does chiplet **1600**, chiplet **1800** includes an RX circuit **1628** which includes decryption Circuit **1640** which includes a counter ctr' **1638** dedicated to the RX circuit **1628**.

[0247] In chiplet **1600**, the counters ctr **1616** and ctr' **1638** were used for full-duplex mode, but in chiplet **1800** they are configured to be used for no-delay half-duplex mode at least partly by no-delay half-duplex mode circuit **1857**.

[0248] Referencing FIG. **19**, a communication sequence **1900** illustrates no-delay half-duplex mode of communication between chiplet-1 (**1924**) and chiplet-2 (**1926**). In some embodiments, chiplet-1 is chiplet **1800** above and stores: a) A session key K that equals r0||r1, b) an LUT generated with random number r0, c) a counter ctr for sending data, and d) a counter ctr' for receiving data. Although FIG. **18** shows KST **1414** shared by encryption circuit **1610** and decryption circuit **1640**, this is optional. A KST need not be stored because values from a KST can be computed on the fly.

[0249] In those embodiments, chiplet-2 stores a) the same session key K that equals r0||r1, b) the same LUT generated with random number r0, c) the counter ctr but for receiving data, and d) the counter ctr' but for sending data. Thus, in chiplet-2 the role of the counters is reversed compared to their role in chiplet-1. A KST need not be stored because values from a KST can be computed on the fly.

[0250] With no-delay half-duplex mode there is a risk of collision of counters ctr and ctr'. It is possible that after encryption of M[i] and M[i'] message blocks on both chiplets, that the counters may collide such that (ctr+i)=(ctr'+i'). This collision may leak some partial information, which may allow for several kinds of attacks. Therefore, the collision is highly undesirable.

[0251] A risk of collision is present when $|ctr-ctr'|<ref\_rate$, where ref_rate is the refresh rate of the session key. The risk may be mitigated by choosing ctr and ctr' differently, for example by choosing ctr probabilistically and choosing ctr' deterministically. For example, during the execution of the sender's and the receiver's Key Generation Functions the counter ctr' can be computed as $ctr' := ctr + 2^{b/2}$. The following are some other options for avoiding collisions:

[0252] a. Assigning ctr' a random value. For example, $ctr' := KST[1] \bmod 2^b$.

[0253] b. Using an initial value IV. For example, ctr||ctr': =IV.

[0254] c. Using the two PRNG's. For example ctr: $=PRNG_0(r1)$ and ctr'$:=PRNG_1(r0)$.

[0255] d. Using a single PRNG. For example, ctr: =PRNG(KST[0]||0) and ctr':=PRNG(KST[0]||1).

[0256] With no-delay half-duplex mode, the control signals are the same control signals as for basic half-duplex mode (SND, ACK, NACK, SND-ACK). In some embodiments, the above control signals are timestamped to resolve conflicts.

[0257] Referencing FIG. **19**, the direction of time for communication sequence **1900** is shown by timeline **1928**. Communication sequence **1900** begins with chiplet authentication **1902** between chiplet-1 (**1924**) and chiplet-2 (**1926**). After chiplet authentication, chiplet-1 and chiplet-2 perform a key exchange **1904**. In some embodiments, chiplet-1 and chiplet-2 perform the key exchange **1904** by executing a Key Exchange Protocol consistent with methods **900** and **1000** of FIGS. **9** and **10**, respectively.

[0258] At step 1, chiplet-1 generates a message M_1. Chiplet-1 then checks if chiplet-2 has sent an SND signal. At step 2, after determining that chiplet-2 has not sent an SND signal, chiplet-1 sends an SND signal to chiplet-2 via transmission **1906**.

[0259] At step 3, chiplet-2 is waiting for M_1 but nevertheless generates message M'_1. But because chiplet-1 has sent an SND signal, chiplet-2 does not send its own SND signal.

[0260] At step 4, chiplet-1 encrypts M_1 by computing ciphertext C_1.

[0261] At step 5, chiplet-2 is still waiting for M_1, but under no-delay half-duplex mode, nevertheless encrypts M'_1 by computing ciphertext C'_1.

[0262] At step 6, via transmission **1908**, chiplet-1 transmits C_1 to chiplet-2 which is waiting for M_1 because of the SND signal from chiplet-1.

[0263] At step 7, chiplet-2 decrypts C_1 to compute M_1. And in step 8, sends an SND signal to chiplet-1 via transmission **1910**. Chiplet-1 is now waiting for M'_1. And in step 9, chiplet-2 transmits C'_1 to chiplet-1 via transmission **1912**.

[0264] In step 10, chiplet-1 decrypts C'_1 to compute M'_1.

[0265] In step 11, chiplet-2 generates message M'_2. And in step 12, chiplet-2 sends an ACK signal to chiplet-1 via transmission **1914**. This ACK signal acknowledges that chiplet-2 has decrypted and verified M_1.

[0266] In step 13, chiplet-1 sends an ACK signal to chiplet-2 via transmission **1916**. The ACK signal acknowledges that chiplet-1 has decrypted and verified M'_1.

[0267] At step 14, chiplet-2 sends an SND signal to chiplet-1 via transmission **1918**. Chiplet-1 is now waiting for M'_2. At step 15, chiplet-2 encrypts M'_2 by computing C'_2. And at step 16, chiplet-2 sends C'_2 to chiplet-1 (and chiplet-1 stops waiting) via transmission **1920**.

[0268] Chiplet-1, in step 17, decrypts C'_2 to compute M'_2. And in step 18, chiplet-1 sends an ACK signal to chiplet-2 via transmission **1922**. The ACK signal acknowledges that chiplet-1 has decrypted and verified M'_2.

[0269] The no-delay half-duplex mode has advantages and disadvantages. Advantages include a high utilization rate of the channel compared with basic half-duplex mode, smaller waiting times, and timeliness of data transmissions. Disadvantages include extra logic (e.g. no-delay half-duplex mode circuit **1857**), a requirement to store an additional counter (as compared with one counter for basic half-duplex mode), and a requirement, in some embodiments, to time-stamp control signals to resolve conflicts.

[0270] The discussion below proceeds to discuss a chiplet **2000** configured for a space-saver mode. Chiplet **2000** is configured to communicate via at least one of basic half-duplex mode or full-duplex mode, but is optimized to save space by avoiding the computation and storage of an entire LUT in the TX circuit **2015**. Instead, components in TX circuit **2015** compute only a target value (e.g. LUT[M[i]]) of the LUT on the fly as needed, and this target value is, in some embodiments, not stored. The operation of communication sequences is, in some embodiments, at least one of sequence **1500** for half-duplex mode or **1700** for full-duplex mode.

[0271] The space optimization for space-saver mode is especially significant for IoT devices, which may include one or more chiplets at least similar to chiplet **2000**. IoT devices are constrained in computing power, memory storage, and access to electrical power, and space saver mode allows an IoT device to conserve resources.

[0272] In a further possible optimization, in some embodiments, an IoT device includes chiplets (e.g. chiplet **2000**) that perform only encryption using space-saver mode, but that do not perform decryption and thus, do not include circuitry for decryption. That is, the IoT device may not include RX circuit **2028** or may include a simplified receiving circuit (now shown), but not one configured for decryption (e.g. lacks key manager **830**, key generation function (receiver) **2032**, and decryption circuit **2040**). Instead, an IoT device may gather data from, for example, sensors and then encrypt and transmit that data to a network device (e.g. a server) (not shown), which performs the decryption.

[0273] Referencing FIG. **20**, chiplet **2000** includes a secure host **2004** that includes a half-duplex/full-duplex modes circuit **2057** that configures local host **2004** for issuing instructions, commands, and data for causing chiplet **2000** to communicate via at least one of half-duplex or full duplex mode in space-saver mode. In some embodiments, half-duplex/full-duplex modes circuit **2057** is a memory bearing executable instructions for causing chiplet **2000** to communicate via at least one of half-duplex or full-duplex mode while in space-saver mode. In some other embodiments, half-duplex/full-duplex modes circuit **2057** is hard-wired logic. And in yet some other embodiments, half-duplex/full-duplex modes circuit **2057** includes both a memory with executable instructions and hard-wired logic.

[0274] Chiplet **2000** includes a TX circuit **2015** that includes a modified key generation function (sender) **2008** that does not return an LUT as output. Instead key generation function (sender) **2008** interfaces with true random number generator TRNG **126** and provides random number r0 (**2017**) to an Encryption Circuit **2010** that computes Encryption Key ((r0, KST, ctr), A, M). That is, Encryption Circuit **2010** does not receive an LUT, but, instead, a random number r_0 to dynamically compute target values of an LUT on the fly as they are needed.

[0275] Encryption Circuit **2010** does not compute, store, or utilize an entire LUT in encryption. Instead, Encryption Circuit **2010** includes an LUT space-saver circuit **2059** that is configured to dynamically compute a target value of an LUT on the fly using random number r0 (**2017**) as discussed below. In some embodiments, space-saver circuit **2059** does not retain the computed target value and therefore does not utilize memory (such as an SRAM) for storing the dynamically computed target value. For computing a target value of an LUT, in some embodiments, the following formula is used: LUT[M[i]]=$PRNG_0$(mix(r0, M[i])). The function mix( ) diffuses values of r0 and M[i] (the message block i) to produce a string that acts as a seed for pseudo-random number generator $PRNG_0$. Method **1100** for encryption is modified. In that, operation **1120** utilizes the dynamically computed LUT[M[i]] rather than target values from an LUT.

[0276] In some embodiments, chiplet **2000** includes an RX circuit **2028** that includes a modified key generation function (receiver) **2032** that computes an LUT **2034** according to the same formula LUT[M[i]]=$PRNG_0$(mix(r0, M[i])). That is, in those embodiments, the foregoing is utilized by key generation function (receiver) **2032** to compute an entire LUT **2034** rather than just a single target value. Decryption Circuit **2040** receives as input this LUT **2034** generated by the foregoing formula, but its operation is otherwise unchanged.

[0277] The mix( ) function is, in some embodiments, computed according method one or method two:

[0278] Method 1: Using Rearrangements.

[0279] a) If:

[0280] a. The input to $PRNG_0$, say, |seed|=128 bits,

[0281] b. The message block size, |M[i]|=16 bits,

[0282] b) Then, we have |r0|=128−16=112 bits.

[0283] c) Then, to compute mix( ) function, the M[i] can be:

[0284] a. Appended—added at the end

[0285] ⇒mix(r0, M[i]):=r0||M[i].

[0286] b. Prefixed—added at the start

[0287] ⇒mix(r0, M[i]):=M[i]||r0.

[0288] c. Prefixed and appended—added half at start and half at end

[0289] ⇒mix(r0, M[i]):=$M[i]_1$||r0||$M[i]_2$.

[0290] d. Diffused—added throughout the r0

[0291] ⇒mix(r0, M[i]):=$M[i]_1||r0_1||M[i]_2||r0_2|| \ldots M[i]_k||r0_k||M[i]_{k+1}$.

[0292] Method 2: Using Functions.

[0293] a) Compute the value of mix( ) function with the help of a mathematical function using r0 and M[i] as inputs.

[0294] b) The potential functions are: Hash function, Compression function, XORing, multiplication, etc.

[0295] In addition to the advantages discussed above for IoT devices, the space-saver mode has several advantages. Advantages include that for small messages, a large computation cost is avoided. These avoided computation costs include the cost of computing all but a few target values of an otherwise large LUT. Generating an LUT, in some embodiments, requires computing all 2^b entries of w bits each (for instance, in one example, 2^{16} entries of 64 bits each). Avoiding the above computation avoids high utilization of a PRNG. A further advantage is, in some embodiments, avoiding the need to store the LUT in memory, such as SRAM.

[0296] The discussion below proceeds to discuss a chiplet **2100** configured for a two-key encryption mode. Chiplet **2100** provides high security for, in some embodiments, at least one of basic half-duplex mode or full-duplex mode, but is configured with two encryption keys for greater security. The operation of communication sequences is, in some embodiments, at least one of sequence **1500** for half-duplex mode or **1700** for full-duplex mode.

[0297] Two-key encryption mode utilizes two session keys: K and K'. The session key K is used for communication from a first chiplet, chiplet-1, to a second chiplet, chiplet-2. And session key K' is used for communication from chiplet-2 to chiplet-1.

[0298] In some embodiments, chiplet-1 is chiplet **2100** above and stores the following for transmitting circuit: a) A session key K that equals r0||r1, b) an LUT generated with random number r0, and c) a counter ctr for sending data. Although FIG. **21** shows encryption circuit **2110** as including KST **2114**, this is optional. A KST need not be stored because values from a KST can be computed on the fly. The chiplet-1 also stores the following for receiving circuit: a) A session key K' that equals r0'||r1", b) an LUT' generated with random number r0', and c) a counter ctr' for receiving data. Although FIG. **21** shows decryption circuit **2140** as including KST' **2136**, this is optional. A KST' need not be stored because values from a KST' can be computed on the fly.

[0299] In those embodiments, chiplet-2 stores the following for transmitting circuit: a) A session key K' that equals r0'||r1', b) an LUT' generated with random number r0', and c) a counter ctr' for sending data. A KST' need not be stored because values from a KST' can be computed on the fly. The chiplet-2 also stores the following for receiving circuit: a) A session key K that equals r0||r1, b) an LUT generated with random number r0, and c) a counter ctr for receiving data. A KST need not be stored because values from a KST can be computed on the fly. Thus, in chiplet-2, the role of the session keys, LUT's, counters and KST's are reversed compared to their role in chiplet-1.

[0300] Referencing FIG. **21**, a chiplet **2100** includes a secure host **2104** that includes a half-duplex/full-duplex modes circuit **2157** that configures local host **2104** for issuing instructions, commands, and data for causing chiplet **2100** to communicate via at least one of half-duplex or full-duplex mode while in two-key encryption mode. In some embodiments, half-duplex/full-duplex modes circuit **2157** is a memory bearing executable instructions for causing chiplet **2100** to communicate via at least one of half-duplex or full-duplex mode while in two-key encryption mode. In some other embodiments, half-duplex/full-duplex modes circuit **2157** is hard-wired logic. And in yet some other embodiments, half-duplex/full-duplex modes circuit **2157** includes both a memory with executable instructions and hard-wired logic.

[0301] Chiplet **2100** includes a TX circuit **2115** with a key generation function (sender) **2108** that utilizes random numbers r0 and r1 to generate a session key K (e.g. where K:=r0||r1). Outputs from key generation function (sender) **2108** to Encryption Circuit **2110** include LUT **2112**, KST **2114**, and counter ctr **2116**. LUT **2112**, KST **2114**, and counter ctr **2116** are stored for use of encryption circuit **2110** for encrypting outgoing data. The foregoing outputs from key generation function (sender) **2108** are for the use of TX circuit **2115** and are not shared with RX circuit **2128** (discussed below). The session key K is shared to the second chiplet, chiplet-2 via the key exchange performed between chiplet-1 and chiplet-2. In some embodiments, the key exchange is performed by executing a Key Exchange Protocol consistent with methods **900** and **1000** of FIGS. **9** and **10**, respectively.

[0302] Chiplet **2100** further includes an RX circuit **2128** with a key generation function (receiver) **2132** that utilizes two different random numbers r0' and r1'. In one embodiment, the values of r0' and r1' are generated by the TX circuit **2115** of the second chiplet, chiplet-2, using a true random number generator, at least similar to TRNG **126**. After this, the chiplet-2 utilizes random numbers r0' and r1' to generate a different session key K' (e.g. where K':=r0'||r1'). The session key K' is shared by the chiplet-2 to the chiplet-1 via the key exchange performed between chiplet-2 and chiplet-1. In another embodiment, the key generation function (receiver) **2132** may be given access to TRNG **126** to generate two different random numbers r0' and r1' for the generation of a different session key K' (e.g. where K':=r0'||r1'). The session key K' is shared by the chiplet-1 to the chiplet-2 via the key exchange performed between chiplet-1 and chiplet-2. In some embodiments, the key exchange is performed by executing a Key Exchange Protocol consistent with methods **900** and **1000** of FIGS. **9** and **10**, respectively. Outputs from key generation function (receiver) **2132** to decryption circuit **2140** include LUT' **2134**, KST' **2136**, and counter ctr' **2138**. At least LUT' **2134**, KST' **2136**, and counter ctr' **2138** are stored for use by decryption circuit **2140**. The foregoing are for the use of RX circuit **2128** and are not shared with TX circuit **2115**.

[0303] The discussion below proceeds relative to FIG. **22** to discuss a chiplet **2200** configured for a two-key space-saver encryption mode. Chiplet **2200** saves on memory use and provides high security for, in some embodiments, at least one of basic half-duplex mode or full-duplex mode. The operation of communication sequences is, in some embodiments, at least one of sequence **1500** for half-duplex mode or **1700** for full-duplex mode.

[0304] Two-key space-saver encryption mode is a space-saver variant of two-key encryption mode. In two-key space-saver encryption mode. both a first chiplet (chiplet-1) and a second chiplet (chiplet-2) use space-saver encryption mode for their transmitting circuit. Storage of an LUT in the TX circuit is thereby avoided. During encryption, the desired LUT target value is computed on the fly without computing or storing an entire table.

[0305] In some embodiments, chiplet-1 is chiplet **2200** above and stores the following for transmitting circuit: a) A session key K that equals r0||r1, and b) a counter ctr for sending data. Although FIG. **22** shows encryption circuit **2210** as including KST **2114**, this is optional. A KST need not be stored because values from a KST can be computed on the fly. The chiplet-1 also stores the following for receiving circuit: a) A session key K' that equals r0'||r1', b) an LUT' generated with random number r0', and c) a counter ctr' for receiving data. Although FIG. **22** shows decryption circuit **2140** as including KST' **2136**, this is optional. A KST' need not be stored because values from a KST' can be computed on the fly.

[0306] In those embodiments, chiplet-2 stores the following for transmitting circuit: a) A session key K' that equals r0'||r1', and b) a counter ctr' for sending data. A KST' need not be stored because values from a KST' can be computed on the fly. The chiplet-2 also stores the following for receiving circuit: a) A session key K that equals r0||r1, b) an LUT generated with random number r0, and c) a counter ctr for receiving data. A KST need not be stored because values from a KST can be computed on the fly. Thus, in chiplet-2, the role of the session keys, LUT's, counters and KST's are reversed compared to their role in chiplet-1.

[0307] Thus, the management of keys is similar to two-key encryption mode, but the avoidance of computing and storing an LUT in the TX circuit is similar to space-saver mode.

[0308] Referencing FIG. **22**, a chiplet **2200** includes a secure host **2204** that includes a half-duplex/full-duplex modes circuit **2257** that configures local host **2204** for issuing instructions, commands, and data for causing chiplet **2200** to communicate via at least one of half-duplex or full-duplex mode in two-key space-saver encryption mode. In some embodiments, half-duplex/full-duplex modes circuit **2257** is a memory bearing executable instructions for causing chiplet **2200** to communicate via at least one of half-duplex or full-duplex mode while in two-key space-saver encryption mode. In some other embodiments, half-duplex/full-duplex modes circuit **2257** is hard-wired logic. And in yet some other embodiments, half-duplex/full-duplex modes circuit **2257** includes both a memory with executable instructions and hard-wired logic.

[0309] Chiplet **2200** includes a TX circuit **2215** with a key generation function (sender) **2208** that utilizes random numbers r0 and r1 to generate a session key K (e.g. where K:=r0||r1). Outputs from key generation function (sender) **2208** to Encryption Circuit **2210** include K, r0 (**2017**), KST **2114**, and counter ctr **2116**, but not an LUT. These outputs are stored for use of Encryption Circuit **2210** for encrypting outgoing data. The foregoing outputs are for the use of TX circuit **2215** and are not shared with RX circuit **2128** (discussed below). The session key K is shared to the second chiplet, chiplet-2 via the key exchange performed between chiplet-1 and chiplet-2. In some embodiments, the key exchange is performed by executing a Key Exchange Protocol consistent with methods **900** and **1000** of FIGS. **9** and **10**, respectively.

[0310] As noted above, key generation function (sender) **2208** does not return an LUT as output. Instead, key generation function (sender) **2208** interfaces with true random number generator TRNG **126** and provides random number r0 (**2017**) to an encryption circuit **2010**, which is described above relative to FIG. **20** and which will not be discussed further relative to FIG. **22**.

[0311] Two-key space-saver encryption mode has advantages and disadvantages. One advantage is that the risk of collision of two counters ctr and ctr'—discussed above regarding no-delay half-duplex mode—is rendered negligible. Another advantage is that the session keys K and K' are refreshed independently of each other. In some embodiments, a key is refreshed with the number of blocks encrypted equals or exceeds ref_rate (the refresh rate). It is possible that K and K' will be used for k blocks at different times. Another advantage is saving the cost of storing an additional LUT. A disadvantage is the requirement, in some embodiments, to store one more session key.

[0312] An additional mode is high-volume data encryption mode, a mode that utilizes data compression. High-volume data encryption mode operates in any of the above communication modes, including for example half-duplex or full-duplex. It is utilized where a high data transfer rate is desired. There are at least the following two modes of implementing high-volume data encryption mode.

[0313] Method 1: Uses loss-less compression and decompression functions. The following are applicable:

[0314] a. Method 1 uses a compression function Comp: $\{0,1\}^q \mapsto \{\mathbf{0,1}\}^b$ in the transmission circuit.

[0315] b. Method 1 uses a decompression function Decomp: $\{0,1\}^b \mapsto \{\mathbf{0,1}\}^q$ in the receiving circuit.

[0316] c. At the Sender's side, the steps are:

[0317] i. Receive a message block M_q of q bits.

[0318] ii. Compress M_q into a b-bit message block: M_b:=Comp(M_q).

[0319] iii. Encrypt M_b to generate a w-bit ciphertext block: C_w:=Enc(M_b).

[0320] iv. Send w-bit ciphertext block C_w to the Receiver.

Message block M_q.
↓ Compression
Compressed Message block M_b.
↓ Encryption
Ciphertext block C_w.
↓ Send to Receiver

[0321] d. At the Receiver's side, the steps are:

[0322] i. Receive w-bit ciphertext block C_w from Sender.

[0323] ii. Decrypt w-bit ciphertext block C_w to generate a compressed b-bit message block: M_b:=Dec (C_w).

[0324] iii. Decompress M_b to a q-bit message block: M_q:=Decomp(M_b).

[0325] iv. Accept M_q.

↓ Receive from Sender
Ciphertext block C_w.
↓ Decryption
Compressed Message block M_b.
↓ Decompression
Message block M_q.

[0326] Method 2: Uses a lossy compression and decompression with error correction. The following are applicable:

[0327] a. Method-2 uses a compression function Comp: $\{0,1\}^w \mapsto \{0,1\}^q$ in the transmission circuit.

[0328] b. Method-2 uses a decompression function Decomp: $\{0,1\}^q \mapsto \{0,1\}^w$ along with error correction in the receiving circuit.

[0329] c. At the Sender's side, the steps are:

[0330] i. Receive a message block M_b of b bits.

[0331] ii. Encrypt M_b to generate a w-bit ciphertext block C_w: C_w:=Enc(M_b).

[0332] iii. Compress C_w into a compressed q-bit ciphertext block C_q: C_q:=Comp(C_w).

[0333] iv. Send compressed q-bit ciphertext block C_q to the Receiver.

Message block M_b.
↓ Encryption
Ciphertext block C_w.
↓ Compression
Compressed Ciphertext block C_q.
↓ Send to Receiver

[0334] d. At the Receiver's side, the steps are:

[0335] i. Receive compressed q-bit ciphertext block C_q from Sender.

[0336] ii. Decompress C_q to obtain a w-bit uncompressed ciphertext block C'_w': C'_w':=Decomp(C_q).

[0337] iii. Correct error in C'_w' to obtain C_w.

[0338] iv. Decrypt C_w to obtain b-bit message block M_b:M_b:=Dec(C_w).

[0339] v. Accept M_b.

↓ Receive from Sender
Compressed Ciphertext block C_q.
↓ Decompression
Ciphertext block C'_w.
↓ Error-Correction
Ciphertext block C_w.
↓ Decryption
Message block M_b.

[0340] The use of compression and decompression has advantages and disadvantages. An advantage is increased performance (e.g. high data transfer rate). A disadvantage is an increased computation cost due to executing compression and decompression functions.

[0341] Some embodiments are now discussed. In discussing exemplary methods, exemplary structures that could perform some actions or functions are discussed. The discussion of structures is not intended to be limiting or exhaustive. Those skilled in the art will appreciate that depending on context, other structures could also be used.

[0342] In some embodiments a cryptographic method is performed at least in part at a first chiplet. The method includes at least with the first chiplet, parsing a message into at least one or more message blocks (e.g. secure host **104** parsing the message). The method further includes at least dynamically generating at least a first target value that is associated with at least a first key (e.g. encryption circuit **810** using LUT **812** or encryption circuit **2010** generating target value on the fly with LUT space-saver circuit **2059**). The method further includes at least dynamically generating at least a second target value that is associated with at least a second key (e.g. at least encryption circuit **810** or encryption circuit **2010** using KST **814** or KST **1414** or generating target value on the fly). The method further includes at least encrypting at least one message block of the at least one or more message blocks to generate at least some ciphertext, the encryption being performed with at least one operation that includes at least one XOR operation, the at least one XOR operation being performed at least in part with the first target value and with at least the second target value, the first target value and the second target value being accessed at partly via the first and second keys, respectively (e.g. with encryption circuit **810** with, for example, encryption algorithm A). The method further includes at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet (e.g. with secure host **104** and TX circuit **815**).

[0343] In some further embodiments, the cryptographic method further includes at least wherein the first key is the message block of the one or more message blocks (e.g. message block **502**A) and the first target value is at least one of a random number or a pseudo-random number accessed as a substitute for the first key (e.g. target value **504**A).

[0344] In some further embodiments, the cryptographic method further includes at least wherein the one or more message blocks are one or more ordered message blocks (e.g. at least message blocks **504**A-**504**D), wherein the second key is a numerical index value associated with a position of the at least one message block within the one or more ordered message blocks (e.g. at least keys **612**A-**612**D corresponding to positions M[0],M[1], M[2], M[3] of FIG. **5**), and wherein the second target value is at least one of a random number or a pseudo-random number (e.g. KST[0]-KST[3] of FIG. **6**).

[0345] In some further embodiments, the cryptographic method further includes at least wherein dynamically generating at least a first target value that is associated with at least a first key includes at least generating a dynamic substitution box (e.g. LUT **500**) that includes at least (i) the first key (e.g. **502**A) and (ii) the first target value (e.g. **504**A), the generating the dynamic substitution box including at least: a) generating a plurality of keys (e.g. **502**A-**502**D) that include the first key, including at least generating the plurality of keys to include at least respective numerical representations of the one or more message blocks (e.g. 0000 for **502**A, 0001 for **502**B, etc.), and b) generating a plurality of target values, including at least generating the first target value as a substitute value for a numerical representation associated with the first key (e.g. **504**A-**504**D). In some further particular embodiments, the cryptographic method further includes at least c) sorting the plurality of keys in the dynamic substitution table, the sorting being based on at least in part on the respective numerical representations of the plurality of keys (e.g. 0000 of **502**A, 0001 of **502**B, etc.) and d) accessing the first target value (e.g. LUT[0], LUT[1], etc.) in the dynamic substitution box by locating the first key, the locating being performed at least in part by searching the sorted numerical representations of the plurality of keys to locate the numerical representation of the first key.

[0346] In some further embodiments, the cryptographic method further includes at least wherein dynamically generating at least a second target value that is associated with at least a second key includes at least generating a lookup table (e.g. KST **600**) that includes at least (i) the second key (e.g. **612**A) and (ii) the second target value (e.g. **614**A), the generating the lookup table including at least, a) generating a plurality of keys (e.g. **612**A-**612**D) that include at least the second key, the plurality of keys including at least respective numerical index values (e.g. 0000 for **612**A, 0001 for **612**B, etc.), and b) generating a plurality of target values (e.g. **614**A-**614**D) that include at least the second target value, respective ones of the plurality of target values being accessible in the lookup table at least in part via the respective numerical index values of the plurality of keys. In some further particular embodiments, the cryptographic method further includes at least accessing the second target value (e.g. KST[0], KST[1], etc.) in the lookup table by locating the second key (e.g. keys 0 of **612**A, 1 of **612**B, 2 of **612**C, etc.), the locating being performed at least in part by searching the respective numerical index values of the plurality of keys to locate a numerical index value associated with the second key.

[0347] In some further embodiments, the cryptographic method includes at least wherein generating the first target value includes at least generating a first random number (e.g. r0 **327**A) with a true random number generator (e.g. **126**, **328**A) and wherein generating the second target value includes at least generating a second random number (e.g. r1 **327**B) with the true random number generator (e.g. **126**, **328**A). In some further particular embodiments, the cryptographic method includes at least wherein generating the first target value additionally includes generating the first target value based at least in part on an output of a pseudo-random number generator (e.g. PRNG0 **322**A) seeded with a seed that includes at least the first random number (e.g. r0), and wherein generating the second target value additionally includes generating the second target value based at least in part on an output of a pseudo-random number generator (e.g. PRNG1 **324**A) seeded with a seed that includes at least the second random number (e.g. r1).

[0348] In some further embodiments, the cryptographic method further includes at least generating a tag based at least in part on the message, a nonce value, and some additional data, and concatenating the tag with at least the message block of the one or more message blocks. The encrypting at least a message block of the at the one or more message blocks further includes encrypting at least the concatenation of the tag with the at least one message block.

[0349] In some further embodiments, the cryptographic method further includes at least wherein the method is performed with a first chiplet that is part of a resource constrained device (e.g. smart camera **1**).

[0350] In some further embodiments, the cryptographic method further includes at least wherein the dynamically generating at least a first target value that is associated with at least a first key includes at least dynamically generating at least a first substitute value for the first key and wherein the generating the first substitute value does not include generating a lookup table containing the first substitute value (see e.g. encryption circuit **2010** with LUT space-saver circuit **2059** with input r0 (**2017**).

[0351] In some further particular embodiments, the cryptographic method further includes at least with at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet with at least one of the following communication modes: a) transmitting in a no-delay half-duplex mode in which the first chiplet encrypts a message block of the one or more message blocks while waiting for a message from the second chiplet, b) transmitting in a space-saver mode in which the first chiplet saves memory resources by generating the first target value without generating a dynamic substitution box, c) transmitting in a two-key encryption mode in which a first security configuration is used for transmitting from the first chiplet to the second chiplet and a second security configuration is used for transmitting from the second chiplet to the first chiplet, d) transmitting in a two-key space-saver mode in which the security configuration is a combination of the space-saver mode and the two-key encryption mode, or e) transmitting in a high performance mode that utilize data compression and data decompression.

[0352] In some embodiments, a cryptographic method is performed at least in part at a second chiplet. The method includes at least dynamically generating a first lookup table (e.g. LUT **500**) that includes a plurality of first target values and a plurality of first keys, a given first target value of the plurality of first lookup values being obtainable based on corresponding first key of the plurality of first keys, and wherein the first lookup table is at least one of usable or configurable as an inverse lookup table (e.g. LUT **500** used as an inverse lookup table, sorted inverse LUT **700**, etc.), for obtaining the corresponding first key based at least in part on the given first target value. The method further includes at least dynamically generating at least a second lookup table (e.g. KST **600**) that includes a plurality of second target values and a plurality of second keys, a given second target value of the plurality of second target values being obtainable based on a corresponding second key of the plurality of second keys. The method further includes at least decrypting at least one ciphertext block of one or more ciphertext blocks to generate at least some plaintext, the decryption being performed at least partly with one or more operations that include at least one or more XOR operations, the one or more XOR operations performed at least in part with the corresponding first key obtained at least partly via the given first target value and with at least the given second target value obtained at least partly via the corresponding second key (See e.g. method **1200**). The method further includes at least verifying the at least some plaintext. And the method further including at least outputting the at least some plaintext responsive to a successful verification of the plaintext.

[0353] In some further embodiments, the cryptographic method further includes at least wherein the at least one XOR operation reverses at least one previous XOR operation, performed at the first chiplet during encryption, of the one or more ciphertext blocks.

[0354] In some further embodiments, the cryptographic method further includes at least receiving ciphertext at the second chiplet transmitted from a first chiplet and parsing the ciphertext into the one or more ciphertext blocks.

[0355] In some further embodiments, the cryptographic method further includes at least wherein the verifying the at least some plaintext includes at least a) separating the at least some plaintext into a first tag and at least a portion of a message, b) computing a second tag based at least in part on the at least a portion of a message, on a nonce, and on additional data, c) comparing the first tag and the second tag, and d) if the first tag and the second tag do not match issuing an error message indicating that verification of the at least some plaintext has failed.

[0356] In some further embodiments, the cryptographic method further includes at least wherein the first target values are at least one of random or pseudo-random numbers and wherein the first lookup table is usable as an inverse lookup table by at least a) selecting a block of ciphertext of the one or more ciphertext blocks, the block of ciphertext including at least a numerical value, b) searching the target values of the first lookup table for a particular target value that matches the numerical value of the selected block of ciphertext, the searching performed with at least a linear search algorithm; and c) based at least in part on the particular target value obtaining a first key of the plurality that corresponds in the first lookup table with the particular target value.

[0357] In some further embodiments, the cryptographic method further includes at least wherein the first target values of the plurality are at least one of random or pseudo-random numbers, and wherein the first lookup table is configurable and usable as an inverse lookup table by at least a) sorting the plurality of first target values, b) selecting a block of ciphertext of the one or more ciphertext blocks, the block of ciphertext including at least a numerical value, c) searching the target values of the first lookup table for a particular target value that matches the numerical value associated with the selected block of ciphertext, the search performed with at least a non-linear search algorithm, and d) based at least in part on the particular target value obtaining a first key of the plurality that is associated in the first lookup table with the particular target value.

[0358] In some embodiments, a cryptographic method is performed at least in part at a first chiplet based on a resource-constrained computing device. The method includes a) at least with the first chiplet, parsing a message into at least one or more message blocks, b) dynamically generating at least a first target value that is associated with at least a first key, c) dynamically generating at least a second target value that is associated with at least a second key, d) encrypting at least a message block of the at least one or more message blocks to generate at least some ciphertext, the encryption being performed with at least one or more operations that include one or more XOR operations, the at least one XOR operation being performed at least in part with the first target value and with at least the second target value, the first target value and the second target value being accessed at partly via the first and second keys, respectively, e) with at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet, f) receiving ciphertext for decryption and transmitting the ciphertext to another computing device for decryption.

[0359] Part Two

[0360] In the encryption and decryption algorithms of methods **1100** and **1200**, the tag is authenticated after the decryption. For example, in method **1100**, if the tag is a CRC, it is computed as T=:CRC(N||A||M), where N is a nonce, A is associated data, and M is the message. Method **1100** then concatenates the tag to the message, as in M||T. The concatenation is then encrypted.

[0361] And in performing decryption, method **1200** decrypts the ciphertext C to obtain M||T and then M and T. Then for authentication, method **1200** then computes tag T':=CRC(N||A||M). The method then verifies the computed CRC T' against the decrypted CRC T. Thus, the decryption takes place before the authentication.

[0362] But decryption takes more time and computing resources than CRC-based authentication. Therefore, for at least some implementations it is desirable to authenticate before incurring the computational expense of decryption.

[0363] One approach is the encrypt-then-tag mode. In the encrypt-then-tag mode, the following are performed during encryption:

[0364] a. Encrypt the message M using the LUT and KST to obtain the ciphertext C_0.

[0365] b. Compute the CRC on the ciphertext C_0 along with the nonce N and the associated data A.

[0366] c. Encrypt the CRC using the LUT and KST to obtain the ciphertext C_1.

[0367] d. Compute the ciphertext C as the concatenation of C_0 and C_1.

[0368] The following steps are performed during decryption:

[0369] a. Parse ciphertext C into C_0 and C_1.

[0370] b. Decrypt the ciphertext C to obtain the CRC.

[0371] c. Recompute the CRC on ciphertext C_0 along with the nonce N and the associated data A.

[0372] d. Verify the computed CRC against the decrypted CRC.

[0373] e. If verification is successful, decrypt the ciphertext C_0 to obtain the message M.

[0374] Before proceeding to discuss specific embodiments, this discussion turns to a high-level overview of three modes of authenticated encryption.

[0375] Referencing FIG. **23**A, a sequence **2300** of computing a tag and then encrypting illustrates tag-then-encrypt mode. This mode is used in method **1100**. Sequence **2300** begins with plaintext **2302**. Plaintext **2302** is input to tag algorithm **2306** along with a TKey **2310**. In some embodiments, tag algorithm **2306** is a CRC routine performed by, for example, CRC engine of **122**. In some alternative embodiments, tag algorithm **2306** is a hash function. In some particular alternative embodiments, tag algorithm **2306** is a keyed hash function that accepts as input key **2304** (e.g. a cryptographic key). Tag algorithm **2306** outputs tag **2312**. In some embodiments, tag **2312** is a CRC. In some alternative embodiments, tag **2312** is a hash.

[0376] Although FIG. **23**A includes a key (TKey **2310**) as input to tag algorithm **2306**, this does not indicate that a key is necessarily used for the tagging. For example, where the tag algorithm **2306** is a CRC, no key is used in computing the CRC. However, a key may be used for encrypting the CRC value. In some embodiments, TKey **2310** is an encryption key that includes at least LUT, KST, ctr. In some other embodiments, TKey **2310** is another type of key. Regardless of the type of key used, for security the CRC must be encrypted. In some embodiments key **2304** and Tkey **2310** are the same key. In other embodiments key **2304** and TKey **2310** are different keys. Various modes that include encryption of a CRC (or other type of tag) are described with reference to FIGS. **23**A-**23**C. And the above discussion applies to those various modes.

[0377] Continuing with sequence **2300**, plaintext **2302** is concatenated (as shown) with the tag **2312**. The concatenation **2308** of plaintext **2302** and tag **2312** is then processed via encryption **2314**, which utilizes key **2304** to produce ciphertext **2316**.

[0378] Thus, in the above sequence **2300** illustrating tag-then-encrypt mode, the tag is computed and concatenated with the plaintext before both are encrypted. The tag-then-encrypt mode has an advantage of high security because the tag **2312** is computed on a plaintext, which is encrypted before the transmission, and tag **2312** is encrypted, which is part of the ciphertext **2316**. A disadvantage is that a computational cost for decryption is incurred even if authentication fails.

[0379] Referencing FIG. **23**B, a sequence **2330** of computing a tag in parallel with encrypting a message illustrates encrypt-and-tag mode. Sequence **2330** begins with plaintext **2302** that is input in parallel to encryption **2314** and to tag algorithm **2306**. Encryption **2314** accepts a key **2304** as input and outputs ciphertext **2316**. Tag Algorithm **2306** accepts a TKey **2310** and outputs tag **2312**. Ciphertext **2316** and tag **2312** are concatenated to form concatenation **2340**.

[0380] Thus, in the above sequence **2330** illustrating encrypt-and-tag mode, a device such as a chiplet computes in parallel (a) a tag **2312** from plaintext **2302**, and (b) ciphertext **2316** from the encryption of plaintext **2302**. Encryption algorithm A, discussed above in tandem with method **1100** can be modified into encrypt-and-tag mode as is discussed below. The encrypt-and-tag mode has an advantage of performing encryption and computing a tag in parallel. A disadvantage is that authentication is verified after the decryption of the entire plaintext.

[0381] Referencing FIG. **23**C, a sequence **2360** of encrypting and computing a tag illustrates encrypt-then-tag mode. Sequence **2360** begins with plaintext **2302** being input to Encryption **2314**. Encryption **2314** also accepts key **2304** as input and then outputs ciphertext **2316**, which may be referred to as message ciphertext **2316**. Tag Algorithm **2370** accepts the ciphertext **2316** along with a TKey **2310** as input and outputs a tag **2376** of the ciphertext **2316**, which may be referred to as tag ciphertext **2376**. The tag **2376** is concatenated with the ciphertext **2316** to form concatenation **2372**.

[0382] Thus, in encrypt-then-tag mode a chiplet encrypts the plaintext **2302** to obtain ciphertext **2316** and then computes a tag **2376** from the ciphertext **2316**. Encryption algorithm A, discussed above in tandem with method **1100** can be modified into encrypt-then-tag mode. Instead of computing the tag as T:=CRC(N||A||M), the tag is computed as T:=CRC(N||A||C), where C is the ciphertext.

[0383] Referencing FIG. **24**, method **2400** provides a method of encryption for encrypt-and-tag mode. The discussion of method **2400** will be in tandem with encryption algorithm E.

[0384] Encryption Algorithm E

```
Enc((LUT, KST, ctr), A, M)

 1. If (ctr + len + 2 + len' + 2 ≥ ref_rate) *
      a. Refresh Session Key (Execute Key Exchange Protocol.)
 2. Compute nonce as N := KST[ctr] †.
 3. Compute CRC on message M as T := CRC (N ‖ A ‖ M).
 4. Parse M[1] ‖ M[2] ‖ ... ‖ M[len] := M.
 5. Parse M'[1] ‖ M'[2] ‖ ... ‖ M'[len'] := T.
 6. Initialize the temporary variable, temp := N ‡.
 7. For i := 1,2, ... , len
      a. Parse t_1 ‖ t_2 ‖ ... ‖ t_m := temp.
      b. Compute val := t_1 ⊕ t_2 ⊕ ... ⊕ t_m♠ .
      c. Compute C[i] := temp := LUT [M[i] ⊕ val] ⊕
      KST[ctr + i] ✠ .
 8. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
 9. Initialize the temporary counter, ctr' := ctr + len + 2.
10. Initialize the temporary variable, temp' := KST[ctr'].
11. For i' := 1,2, ... , len'
      a. Parse t_1' ‖ t_2' ‖ ... ‖ t_m' := temp'.
      b. Compute val' := t_1' ⊕ t_2' ⊕ ... ⊕ t_m'♠ .
      c. Compute C'[i'] := temp' := LUT[M'[i'] ⊕ val'] ⊕
      KST[ctr' + i'] ✠ .
12. Compute C'[len'] := C'[len'] ⊕ KST[ctr' + len' + 1].
13. Update counter ctr := ctr + len + 2 + len' + 2.
14. Compute ciphertext C := C[1] ‖ C[2] ‖ ... ‖ C[len] ‖ C'[1] ‖ C'[2] ‖ ...
    ‖ C'[len'].
15. Return C and ctr.
 *: If counter is initialized as ctr := KST[0] mod 2^b, then, depending
    on the implementation, the condition will be:
      a. (blk_ctr + len + 2 ≥ ref_rate), or
      b. (ctr + len + 2 − KST[0] ≥ ref_rate).
 †: Nonce can also be randomized as:
      d. Compute b := N & 0 × 01. (For the first value, N := KST[0])
      e. Compute idx := idx + 1.     (For the first value, idx := 0)
      f. Compute N := PRNG_{1−b}(r_b ‖ idx).
 ‡: Variable temp can also be computed as temp := LUT[N].
 ♠: For some Integer s, variable val can also be computed as:
        val := t_1 ⊕ (t_2 << s) ⊕ ... ⊕ (t_m << s(m − 1))
 ✠: C[i] can also be computed as:
      a. Compute temp := LUT[M[i] ⊕ val].
      b. Compute C[i] := temp ⊕ KST[ctr + i].
```

[0385] Encryption algorithm E has a number of changes relative to encryption algorithm A. But first, unchanged are methods **900** and **1000** for key generation for sender and receiver, respectively. Also, the inputs and outputs for encryption algorithm E are the same as for encryption algorithm A. These changes are discussed below in the context of the discussion of the operations of method **2400**.

[0386] Algorithm E, as well as Algorithms F through H discussed below, have operations that specifically refer to a CRC. This is not intended to be limiting. The CRC is just one example of a tag algorithm. Those skilled in the art will recognize that where a CRC is specifically referred to, that other types of tag algorithms, such as hash functions, could be substituted.

[0387] Returning to reference FIG. **24**, after a start operation **2401**, method **2400** proceeds to operation **2402** of inputting the encryption key (LUT, KST, ctr), associated data A, and message M for encryption.

[0388] Control moves to operation **2404** of determining if the block count exceeds ref_rate, where ref_rate is the refresh rate of the session key. Encryption algorithm E makes this determination as: If (ctr+len+2+len'+2) is greater than or equal to ref_rate. A difference from encryption algorithm A is that len', the length of the CRC is included in the condition for refreshing the session key. And the additional 2 is for processing of a nonce and the last block of tag ciphertext (below).

[0389] If it is determined that the block count exceeds ref_rate, then control moves to operation **2406** for refreshing the session key. This is unchanged from method **1100** of FIG. **11** and reference is made to that discussion. After the session key is refreshed, control moves to operation **2408** below.

[0390] If it is determined that the block count does not exceed the ref_rate, then in operation **2408** nonce N is initialized. This operation is unchanged from operation **1110** of method **1100**. Reference is made to the discussion of operation **1110**.

[0391] Control moves to operation **2410** of computing tag T on N||A||M. This operation is unchanged from operation **1112** of method **1100**. Reference is made to the discussion of operation **1112**.

[0392] Control moves to operation **2414** of Parsing M into M[1], M[2], . . . , M[len]. This is different than operation **1114** where the concatenation of M||T is parsed. In method **2400** the message M and the CRC are parsed separately. The message M is parsed in operation **2414** and the CRC is parsed in operation **2426** (discussed below).

[0393] Control moves to operation **2416** of initializing a counter variable i with 1.

[0394] A loop is executed that includes operation **2418** of determining if the counter i is less than or equal to the number of message blocks len. If the counter i is greater than len, the control moves to exiting the loop and proceeding to operation **2424** discussed below. If the counter i is less than or equal to len, then control stays in the loop to execute operation **2420** of computing ciphertext block C[i] and then to operation **2422** of updating the counter i. This loop is unchanged from operations **1118**, **1120**, and **1122** of method **1100** of FIG. **11**, and reference is made to that discussion.

[0395] Control moves to operation **2424** of computing the last ciphertext block C[len]. This operation is unchanged from operation **1124** of method **1100**. Reference is made to that discussion.

[0396] Control moves to operation **2426** which parses the tag T into tag blocks M' [1], M' [2], . . . M'[len']. M'[ ] refers to tag blocks (i.e. the parsed blocks of tag) and len' is the number of tag blocks. In some embodiments, the size of the tag blocks is the same as the size of the message blocks and is governed by the value "b" discussed above. Operation **2426** corresponds to step 5 of encryption algorithm E.

[0397] Control moves to operation **2428** which initializes a counter variable i' to 1. Encryption algorithm E includes at step 9, initializing an additional counter ctr':=ctr+len+2, which is the current value of the counter ctr, plus len which is the number of message blocks, plus 2. Encryption algorithm E further includes initializing a temporary variable, temp' to KST[ctr'], which is the KST target value associated with a key value equal to ctr'.

[0398] A loop is executed that includes operation **2430** which determines if the counter i' is less than or equal to the number of tag blocks len'. If no, then control exits the loop and proceeds to operation **2436** discussed below. If yes, then control stays in the loop to execute operation **2432** which computes tag ciphertext block C'[i'] where C'[i'] is a tag ciphertext block (i.e. ciphertext of a tag block). The loop then continuing to operation **2434** which updates the counter i' before repeating the loop. The loop repeats until operation **2430** evaluates to yes, then control moves to operation **2436**.

[0399] This loop is at least substantially similar to operations **1118**, **1120**, and **1122** of method **1100** of FIG. **11**, except that the variable temp' replaces temp, temp' is parsed into t'[ ] blocks instead of t[ ] blocks and the variable val' replaces val. Therefore, reference is again made to that discussion.

[0400] After control exits the loop, operation **2436** processes the last tag ciphertext block C'[len']. This operation is substantially similar to operation **1124** of method **1100** except that the ciphertext block is C' instead of C, the number of blocks is len' for the number of CRC ciphertext blocks instead of len for the number of message blocks, and the counter variable used is ctr' instead of ctr. Reference is made to that discussion.

[0401] Control moves to operation **2438** of updating the counter ctr. In some embodiments, in accordance with encryption algorithm E, the update is ctr:=ctr+len+2+len'+2, which is the usual update from operation **1126** plus len' which is the number of tag blocks plus an additional 2 for processing of the nonce value and the last tag ciphertext block.

[0402] Control moves to operation **2440** of concatenating C[1], C[2], . . . C[len] and C' [1], C' [2], . . . C'[len'], to form the final ciphertext C. That is, the message ciphertext blocks corresponding to the message M are concatenated, the ciphertext blocks corresponding to the CRC (e.g. the tag) are concatenated, and then the tag ciphertext is appended to the message ciphertext to form the final ciphertext C.

[0403] Control moves to operation **2446** of outputting C and ctr before moving to a stop operation **2448**.

[0404] Referencing FIG. **25**, method **2500** provides a method of decryption for encrypt-and-tag mode. Method **2500** decrypts the ciphertext C output by method **2400**. The discussion of method **2500** will be in tandem with decryption algorithm F.

[0405] Decryption Algorithm F

Dec((LUT, KST, ctr), A, C)

1. Compute nonce as N := KST[ctr] †.
2. Parse C[1] ‖ C[2] ‖ ... ‖ C[len] ‖ C'[1] ‖ C'[2] ‖ ... ‖ C'[len'] := C.
3. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
4. Initialize the temporary variable, temp := N ‡.
5. For i := 1,2, ... , len

-continued

Dec((LUT, KST, ctr), A, C)

a. Parse $t_1 \| t_2 \| \ldots \| t_m$:= temp.
b. Compute val := $t_1 \oplus t_2 \oplus \ldots \oplus t_m$♠ .
c. Compute temp := C[i]✠ .
d. Compute M[i] := LUT^{-1} [C[i] $\oplus$ KST[ctr + i]] $\oplus$ val✠ .
6. Compute message M := M[1] ‖ M[2] ‖ ... ‖ M[len].
7. Initialize the temporary counter, ctr' := ctr + len + 2 ‡.
8. Compute C'[len'] := C'[len'] $\oplus$ KST[ctr' + len' + 1].
9. Initialize the temporary variable, temp' := KST[ctr'] ‡.
10. For i' := 1,2, ... , len'
a. Parse $t_1' \| t_2' \| \ldots \| t_m'$:= temp'.
b. Compute val' := $t_1' \oplus t_2' \oplus \ldots \oplus t_m'$ ♠ .
c. Compute temp' := C'[i']✠ .
d. Compute M'[i'] := LUT^{-1}[C'[i'] $\oplus$ KST[ctr' + i']] $\oplus$ val'✠ .
11. Extract T := M'[1] ‖ M'[2] ‖ ... ‖ M'[len'].
12. Compute CRC on message M as T' := CRC(N ‖ A ‖ M).
13. If (T = = T')
a. Update counter ctr := ctr + len + 2 +len' + 2.
b. Return M and ctr.
14. Else
a. Return Error.

†: Nonce can also be randomized as:
g. Compute b := N & 0 × 01. (For the first value, N := KST[0])
h. Compute idx := idx + 1. (For the first value, idx := 0)
i. Compute N := $PRNG_{1-b}(r_b \| idx)$.

‡: Variable temp can also be computed as temp := LUT[N].

♠: For some Integer s, variable val can also be computed as:
val := $t_1 \oplus (t_2 \ll s) \oplus \ldots \oplus (t_m \ll s(m-1))$

✠: M[i] can also be computed as:
e. Compute temp := C[i] $\oplus$ KST[ctr + i].
f. Compute M[i] := LUT^{-1}[temp] $\oplus$ val.

[0406] Decryption algorithm F has a number of changes relative to decryption algorithm B. But first, unchanged are methods **900** and **1000** for key generation for sender and receiver respectively. Also, the inputs and outputs for decryption algorithm F are the same as for decryption algorithm B. Changes from decryption algorithm B are discussed below in the context of the discussion of the operations of method **2500**.

[0407] Returning to reference FIG. **25**, after a start operation **2502**, method **2500** proceeds to operation **2504** of inputting the decryption key (LUT, KST, ctr), associated data A, and ciphertext C for decryption.

[0408] Control moves to operation **2506** of initializing Nonce N. This operation is unchanged from operation **1206** of method **1200**. Reference is made to that discussion.

[0409] Control moves to operation **2508** of parsing ciphertext C into ciphertext blocks, including message ciphertext blocks denominated C[ ] associated with the encrypted message and tag ciphertext blocks denominated C'[ ] associated with the encrypted tag. More specifically, in some embodiments, C is parsed into C[1], C[2], . . . C[len] and C'[1], C'[2], . . . C'[len']. In the foregoing, len is once again the number of ciphertext blocks associated with the message M and len' is the number of ciphertext blocks associated with the CRC.

[0410] Control moves to operation **2510** of processing the last message ciphertext block, C[len]. This operation is unchanged from operation **1210** of method **1200** and therefore reference is made to the discussion of operation **1210** above.

[0411] Control moves to operation **2512** of initializing counter variable i to 1. Consistent with some embodiments, decryption algorithm F also includes initializing a temp variable to be equal to nonce N. This operation is unchanged from that discussed in association with operation **1212** of method **1200**. Reference is therefore made to the discussion related to operation **1212** above.

[0412] A loop is executed that includes operation **2514** of determining if the counter i is less than or equal to the number of message blocks len. If no, then control exists the loop and proceeds to operation **2520** (below). If yes, then control stays in the loop to execute operation **2516** which computes decrypted message block M[i] and then to operation **2518** which updates the counter i. This loop is unchanged from operations **1214**, **1216**, and **1218** of method **1200** and reference therefore is made to that discussion regarding method **1200**.

[0413] Upon exiting the above loop, control moves to operation **2520** of concatenating the message blocks M[1], M[2], . . . , M[len] to form the complete decrypted message M. Operation **2520** is different from operation **1220** of method **1200** in that the concatenated message blocks form only message M. In operation **1220** the concatenated blocks form a concatenation of the message M and a tag T, as in M‖T. However, in method **2500** the processing of tag ciphertext blocks is performed separately.

[0414] The processing of the tag ciphertext blocks begins, in some embodiments, with operation **2522** of processing the last tag ciphertext block, that is C'[len']. Except for the substitution of len' for len and C' for C, this operation is unchanged from operation **1210** of method **1200**. Reference is made to discussion of operation **1210**.

[0415] Consistent with some embodiments, decryption algorithm F also includes initializing a counter ctr'. In some particular embodiments, this takes the form of, for example, ctr':=ctr+len+2, which is the counter ctr plus len for the number of message blocks plus 2 for the processing of the nonce in operation **2506** and the last message ciphertext block in operation **2510**.

[0416] Control moves to operation **2524** of initializing counter variable i' with 1. Consistent with some embodiments, decryption algorithm F also includes initializing a variable temp' as equal to KST[ctr'].

[0417] A loop is executed that includes operation **2526** of determining if the counter i' is less than or equal to len', which is the number of tag ciphertext blocks. If no, then control exits the loop and proceeds to operation **2532** (below). If yes, then control stays in the loop to execute operation **2528** of computing decrypted tag block M'[i] and then to operation **2530** which updates the counter i'. This loop is analogous to the operations **1214**, **1216**, and **1218** of method **1200**, except that the variable temp' is substituted for temp, temp' is parsed into t'[ ] blocks instead of t[ ] blocks and the variable val' is substituted for val. With those changes in mind, reference therefore is made to that discussion regarding method **1200**.

[0418] Control moves to operation **2532** which concatenates the decrypted tag blocks M'[1], M'[2], . . . M'[len'] to obtain the complete decrypted tag T (e.g. a CRC). This is different from operation **1220** of method **1200** where the concatenated blocks M[1], M[2], . . . M[len] yielded a concatenation of the message and the tag, as in M‖T. In operation **2500** the ciphertext blocks associated with the tag T are processed separately from the ciphertext blocks associated with the message M.

[0419] Control moves to operation **2534** of computing a tag T' (e.g a CRC) on N‖A‖M. This step is at least similar to the operation **1222** of the method **1200**. Reference is made to that discussion.

[0420] Control moves to operation **2536** of determining if the computed tag T' is equal to the decrypted tag T. If no, then control moves to operation **2542** of outputting an error message and then to stop operation **2544**.

[0421] If yes, then control moves to operation **2538** of updating the counter ctr. Referencing decryption algorithm F, in some embodiments, operation **2538** is performed by ctr:=ctr+len+2+len'+2, which includes the usual update of ctr plus the number of tag blocks plus 2 for the processing of the nonce and the last tag ciphertext block. Control then moves to operation **2540** which is the outputting of M and ctr. Finally, there is a stop operation **2544**.

[0422] Referencing FIG. **26**, method **2600** provides a method of encryption for encrypt-then-tag mode. In this mode, encryption of a message M and computation of a tag T on the encrypted message is performed first before they are joined to form a final ciphertext C. The discussion of method **2600** will be in tandem with encryption algorithm G

[0423] Encryption Algorithm G

```
Enc((LUT, KST, ctr), A, M)

1. If (ctr + len + 2 + len' + 2 ≥ ref_rate) *
     a. Refresh Session Key (Execute Key Exchange Protocol.)
2. Compute nonce as N := KST[ctr] †.
3. Parse M[1] ‖ M[2] ‖ ... ‖ M[len] := M.
4. Initialize the temporary variable, temp := N ‡.
5. For i := 1,2, ... , len
     a. Parse t_1 ‖ t_2 ‖ ... ‖ t_m := temp.
     b. Compute val := t_1 ⊕ t_2 ⊕ ... ⊕ t_m♠ .
     c. Compute C[i] := temp := LUT[M[i] ⊕ val] ⊕
     KST[ctr + i]✠ .
6. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
7. Compute ciphertext C := C[1] ‖ C[2] ‖ ... ‖ C[len].
8. Compute CRC on ciphertext C as T := CRC(N ‖ A ‖ C).
9. Parse M'[1] ‖ M'[2] ‖ ... ‖ M'[len'] := T.
10. Initialize the temporary counter, ctr' := ctr + len + 2.
11. Initialize the temporary variable, temp' := KST[ctr']♣ .
12. For i' := 1,2, ... , len'
     a. Parse t_1' ‖ t_2' ‖ ... ‖ t_m' := temp'.
     b. Compute val' := t_1' ⊕ t_2' ⊕ ... ⊕ t_m'♠ .
     c. Compute C'[i'] := temp' := LUT[M'[i'] ⊕ val'] ⊕
     KST[ctr' + i'] ✠ .
13. Compute C'[len'] := C'[len'] ⊕ KST[ctr' + len' + 1].
14. Update counter ctr := ctr + len + 2 + len' + 2.
15. Compute ciphertext C := C ‖ C'[1] ‖ C'[2] ‖ ... ‖ C'[len'].
16. Return C and ctr.
*: If counter is initialized as ctr := KST[0] mod 2^b, then, depending
   on the implementation, the condition will be:
     a. (blk_ctr + len + 2 ≥ ref_rate), or
     b. (ctr + len + 2 − KST[0] ≥ ref_rate).
†: Nonce can also be randomized as:
     g. Compute b := N & 0 × 01. (For the first value, N := KST[0])
     h. Compute idx := idx + 1.    (For the first value, idx := 0)
     i. Compute N := PRNG_{1−b}(r_b ‖ idx).
‡: Variable temp can also be computed as temp := LUT[N].
♣: temp' can also be initialized as C[len]. This will reduce the cost of
   invoking one PRNG.
♠: For some Integer s, variable val can also be computed as:
       val := t_1 ⊕ (t_2 << s) ⊕ ... ⊕ (t_m << s(m − 1))
✠: C[i] can also be computed as:
     e. Compute temp := LUT[M[i] ⊕ val].
     f. Compute C[i] := temp ⊕ KST[ctr + i].
```

[0424] Encryption algorithm G has a number of changes relative to encryption algorithm A. But first, unchanged are methods **900** and **1000** for key generation for sender and receiver, respectively. Also, the inputs and outputs for encryption algorithm G are the same as for encryption algorithm A. These changes from encryption algorithm A are discussed below in the discussion of the operations of method **2600**.

[0425] Returning to reference FIG. **26**, after a start operation **2602**, the control moves to operation **2604** of inputting the encryption key (LUT, KST, ctr), associated data A, and message M to be encrypted.

[0426] Control moves to operation **2606** of determining if a block count exceeds the session key refresh rate, ref_rate. Consistent with some embodiments, Encryption algorithm G makes this determination as: If (ctr+len+2+len'+2) is greater than or equal to ref_rate. A difference from encryption algorithm A is that len', the number of the tag blocks plus an additional 2, for processing the nonce and the last block of ciphertext is included in the condition for refreshing the session key.

[0427] If operation **2606** evaluates to yes, then control moves to operation **2608** of refreshing the session key. Operation **2608** is unchanged from operation **1108** of method **1100**. Therefore, the discussion of operation **1100** is referenced. After the refreshing of the session key, control moves to operation **2610** below.

[0428] Returning to operation **2606**, if operation **2606** evaluates to no, the control moves to operation **2610** of initializing Nonce N. Operation **2610** is unchanged from operation **1110** of method **1100**. Therefore, reference is made to the discussion above of operation **1110**.

[0429] Control moves to operation **2612** of Parsing M into M[1], M[2], . . . , M[len]. This is different than operation **1114** where the concatenation of M‖T is parsed. In method **2600**, the message M and the tag (e.g. CRC) are parsed separately.

[0430] Control moves to operation **2614** of initializing a counter variable i with 1. For some specific embodiments, encryption algorithm G also initializes temporary variable temp to nonce N.

[0431] A loop is executed that includes operation **2616** of determining if the counter i is less than or equal to the number of message blocks len. If no, control exits the loop and proceeds to operation **2622** (below). If yes, then control stays in the loop to execute operation **2618** which encrypts message block M[i] to compute message ciphertext block C[i] and then to operation **2620** which updates the counter i. The loop is repeated with i incremented on each loop until operation **2616** evaluates to no and control exits the loop. This loop is unchanged from operations **1118**, **1120**, and **1122** of method **1100** of FIG. **11**, and reference is made to that discussion.

[0432] Control moves to operation **2622** of computing the last message ciphertext block C[len]. This operation is unchanged from operation **1124** of method **1100**. Reference is made to that discussion.

[0433] Control moves to operation **2624** of concatenating message ciphertext blocks C[1], C[2], . . . C[len] to obtain C, which is a ciphertext of just message M. This is different from operation **1128** of method **1100** where the concatenation of the C[ ] blocks yields a ciphertext of a concatenation of a message M and a tag T, that is M‖T. This operation **2624** concludes the encrypting of the message M. The next operations include computing and encrypting a tag T.

[0434] Control moves to operation **2626** of computing a tag T (e.g. a CRC) on N‖A‖C, where C is the message ciphertext computed above. Then in operation **2628**, T is parsed into tag blocks (denominated M'[ ]), that is M' [1], M' [2], . . . M'[len'].

[0435] Control moves to operation **2630** of initializing a counter variable i' to 1. Encryption algorithm G includes initializing an additional counter ctr':=ctr+len+2, which is the current value of the counter ctr, plus len which is the number of message blocks, plus 2. Encryption algorithm G further includes initializing a temporary variable, temp' to KST[ctr'].

[0436] A loop is executed that includes operation **2632** of determining if the counter i' is less than or equal to the number of tag blocks, which is len'. If no, control exits the loop and proceeds to operation **2638** (below). If yes, then control stays in the loop to execute operation **2634** of encrypting tag block M'[i'] to compute tag ciphertext block C'[i']. The loop then continues to operation **2636** which updates the counter i' before repeating the loop. The loop repeats until the counter i' exceeds len', then control moves to operation **2638**.

[0437] This loop is at least substantially similar to operations **1118**, **1120**, and **1122** of method **1100**, except that the variable temp' replaces temp, temp' is parsed into t'[ ] blocks instead of t[ ] blocks and the variable val' replaces val. Therefore, reference is again made to that discussion of operations **1118**, **1120**, and **1122**.

[0438] After control exits the loop, operation **2638** processes the last tag ciphertext block C'[len']. This operation is substantially similar to operation **1124** of method **1100** except that the ciphertext block is C' instead of C, the number of blocks is len' for the number of tag ciphertext blocks instead of len for the number of message blocks, and the counter variable used is ctr' instead of ctr. Reference is made to that discussion of operation **1100**.

[0439] Control moves to operation **2640** of updating the counter ctr. In some embodiments, in accordance with encryption algorithm G, the update is ctr:=ctr+len+2+len'+2, which in addition to the usual update from operation **1126** includes adding len' which is the number of tag blocks plus an additional 2 for processing of the nonce value and the last tag ciphertext block.

[0440] Control moves to operation **2642** of appending C' [1], C' [2], . . . C'[len'], to C to form the final ciphertext C.

[0441] Control moves to operation **2644** of outputting C and ctr before moving to a stop operation **2646**.

[0442] Referencing FIG. **27**, method **2700** provides a method of decryption for encrypt-then-tag mode. Method **2700** is directed at verifying and decrypting the ciphertext C created in method **2600**. The discussion of method **2700** will be in tandem with decryption algorithm H.

[0443] Decryption Algorithm H

Dec((LUT, KST, ctr), A, C)

1. Compute nonce as N := KST[ctr] †.
2. Parse C ‖ C'[1] ‖ C'[2] ‖ ... ‖ C'[len'] := C.
3. Initialize the temporary counter, ctr' := ctr + len + 2 ‡.
4. Compute C'[len'] := C'[len'] ⊕ KST[ctr' + len' + 1].
5. Initialize the temporary variable, temp' := KST[ctr'] ♣.
6. For i' := 1,2, ... , len'
   a. Parse $t_1' \| t_2' \| \ldots \| t_m'$:= temp'.
   b. Compute val' := $t_1' \oplus t_2' \oplus \ldots \oplus t_m'$ ♠.

-continued

Dec((LUT, KST, ctr), A, C)

   c. Compute temp' := C'[i'] ✠.
   d. Compute M'[i'] := LUT^{-1}[C'[i'] ⊕ KST[ctr' + i']] ⊕ val' ✠.
7. Extract T := M'[1] ‖ M'[2] ‖ ... ‖ M'[len'].
8. Compute CRC on ciphertext C as T' := CRC(N ‖ A ‖ C).
9. If (T ≠ T')
   a. Return Error.
10. Parse C[1] ‖ C[2] ‖ .... ‖ C[len] := C.
11. Compute C[len] := C[len] ⊕ KST[ctr + len + 1].
12. Initialize the temporary variable, temp := N ‡.
13. For i := 1,2, ... , len
    a. Parse $t_1 \| t_2 \| \ldots \| t_m$:= temp.
    b. Compute val := $t_1 \oplus t_2 \oplus \ldots \oplus t_m$ ♠.
    c. Compute temp := C[i] ✠.
    d. Compute M[i] := LUT^{-1}[C[i] ⊕ KST[ctr + i]] ⊕ val' ✠.
14. Compute message M := M[1] ‖ M[2] ‖ ... ‖ M[len].
15. Update counter ctr := ctr + len + 2 + len' + 2.
16. Return M and ctr.

†: Nonce can also be randomized as:
   a. Compute b := N & 0 × 01. (For the first value, N := KST[0])
   b. Compute idx := idx + 1. (For the first value, idx := 0)
   c. Compute N := $PRNG_{1-b}(r_b \| idx)$.

♣: temp' can also be initialized as C[len]. This will reduce the cost of invoking one PRNG.

‡: Variable temp can also be computed as temp := LUT[N].

♠: For some Integer s, variable val can also be computed as:
   val := $t_1 \oplus (t_2 \ll s) \oplus \ldots \oplus (t_m \ll s(m - 1))$

✠: M[i] can also be computed as:
   e. Compute temp := C[i] ⊕ KST[ctr + i].
   f. Compute M[i] := LUT^{-1}[temp] ⊕ val.

[0444] Decryption algorithm H has a number of changes relative to decryption algorithm B. But first, methods **900** and **1000** for key generation for sender and receiver respectively are unchanged. Also, the inputs and outputs for decryption algorithm H are the same as for decryption algorithm B. The changes relative to decryption algorithm B are discussed below in the discussion of the operations of method **2700**.

[0445] Returning to reference method **2700**, after a start operation **2702**, the control moves to operation **2704** of inputting the decryption key (LUT, KST, ctr), associated data A, and ciphertext C to be decrypted.

[0446] Control moves to operation **2706** of initializing Nonce N. This operation is unchanged from operation **1206** of method **1200**. Reference is made to that discussion.

[0447] Control moves to operation **2708** of parsing ciphertext C into message ciphertext C and tag ciphertext blocks C' [1], C' [2], . . . C'[len'], len' is the number of tag ciphertext blocks. That is tag ciphertext C' (encrypted tag) which was previously appended to C is removed and parsed. The result is message ciphertext C and C' [1], C' [2], . . . C'[len'].

[0448] Control moves to operation **2710** of processing the last tag ciphertext block, C'[len']. Consistent with some embodiments, decryption algorithm H performs this operation by first initializing a temporary counter ctr':=ctr+len+2, where ctr is the current value of counter and len is the number of message ciphertext blocks. Then the following computation is performed: C'[len']:=C'[len'] ⊕KST[ctr'+len'+1], len' is the number of tag ciphertext blocks. Thus, the last tag ciphertext block C'[len'] is set to C'[len'] XOR'd with the subexpression KST[ctr'+len'+1]. The KST[ctr'+len'+1] is the target value in the KST associated with a key equal to (ctr'+len'+1). This reverses the computation of the last tag ciphertext block in operation **2638**.

[0449] Control moves to operation **2712** of initializing a counter variable i' with 1. Consistent with some embodiments, decryption algorithm H also initializes a temp' variable as equal to KST[ctr']. In another embodiment, the variable temp' could be initialized as equal to C[len], that is the last w bits of the message ciphertext C. A difficulty is that according to FIG. **27**, ciphertext C is not parsed until operation **2728** (below). There are at least two possible solutions. A first solution is to access the last w bits of C directly, regardless of whether C is parsed or not. It will be recalled that w is the length in bits of the ciphertext blocks (See discussion of w bits relative to FIG. **5**). A second solution is to move operation **2728** to occur before operation **2712**. Decryption algorithm H also initializes counter variable ctr' as ctr+len+2.

[0450] A loop is executed that includes operation **2714** which determines if the counter i' is less than or equal to the number of tag ciphertext blocks len'. If no, then control exits the loop and proceeds to operation **2720** (below). If yes, then control stays in the loop to execute operation **2716** of decrypting tag ciphertext block C'[i'] to compute decrypted tag block M'[i'] and then to operation **2718** of updating the counter i'. The loop is repeated until operation **2714** evaluates to no. This loop is analogous to the operations **1214**, **1216**, and **1218** of method **1200**, except that the variable temp' is substituted for temp, temp' is parsed into t'[ ] blocks instead of t[ ] blocks and the variable val' is substituted for val. With those changes in mind, reference therefore is made to that discussion regarding method **1200**.

[0451] Control moves to operation **2720** of concatenating the decrypted tag blocks M' [1], M' [2], . . . M'[len'] to obtain the complete tag T. As will be recalled, in operation **2626** of method **2600**, the tag T was computed on N||A||C, that is partly on the ciphertext. Therefore, the tag T is a tag partly on ciphertext. The foregoing is in contrast to operation **1220** of method **1200** where the concatenated blocks M[1], M[2], . . . M[len] yielded a concatenation of the message and the tag, as in M||T. And in operation **1220**, the tag was on N||A||M, partly on the message, not on ciphertext.

[0452] Control moves to operation **2722** which computes a tag T' (e.g a CRC) on N||A||c.

[0453] Control moves to operation **2724** which determines if the computed tag T' is equal to the decrypted tag T. If no, then control moves to operation **2726** of outputting an error message, and then to stop operation **2746**.

[0454] If the operation **2724** evaluates to yes, then control moves to operation **2728** of parsing message ciphertext C into message ciphertext blocks C[1], C[2], . . . C[len].

[0455] Control moves to operation **2730** of processing the last message ciphertext block C[len]. This operation is unchanged from operation **1210** of method **1200** and therefore reference is made to the discussion of operation **1210** above.

[0456] Control moves to operation **2732** of initializing counter variable i to 1. Consistent with some embodiments, decryption algorithm H includes initializing a temp variable to be equal to nonce N. This operation is unchanged from that discussed in association with operation **1212** of method **1200**. Reference is therefore made to the discussion related to operation **1212** above.

[0457] A loop is executed that includes operation **2734** of determining if the counter i is less than or equal to the number of message blocks, len. If no, control exits the loop and proceeds to operation **2740** (below). If yes, then control stays in the loop to execute operation **2736** of decrypting C[i] to compute decrypted message block M[i] and then to operation **2738** of updating the counter i. The loop repeats until operation **2734** evaluates to no. This loop is unchanged from operations **1214**, **1216**, and **1218** of method **1200** and reference therefore is made to that discussion regarding method **1200**.

[0458] Upon exiting the above loop, control moves to operation **2740** which concatenates the message blocks M[1], M[2], . . . , M[len] to form the complete decrypted message M. Operation **2740** is different from operation **1220** of method **1200** in that the concatenated message blocks form only message M. In operation **1220**, the concatenated blocks form a concatenation of the message M and a tag T, as in M||T.

[0459] Control moves to operation **2742** of updating counter ctr. Consistent with some embodiments, decryption algorithm H updates counter with the following formula: ctr: =ctr+len+2+len'+2. Thus, the ctr update additionally includes adding the number of tag blocks len' plus an additional 2 for the processing of the nonce and the last tag ciphertext block.

[0460] Control moves to operation **2744** which outputs M and ctr as the output of method **2700**. Control then moves to a stop operation **2746**.

[0461] Some embodiments are now discussed. In discussing exemplary methods or circuits, exemplary structures that could perform some actions or perform some functions are discussed. The discussion of structures is not intended to be limiting or exhaustive. Those skilled in the art will appreciate that depending on context, other structures could also be used.

[0462] In some embodiments, a cryptographic method (e.g. method **2400**) is performed in a first chiplet. The cryptographic method includes at least (1) with one or more processing devices, computing a tag on a nonce (e.g. **119**), a message (e.g. **117**), and other data (e.g. associated data **121**), (2) parsing the message into one or more message blocks to create one or more ordered message blocks (e.g. blocks M[0], M[1], etc. of FIG. **5**), (3) encrypting the one or more ordered message blocks to obtain one or more ordered message ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations, (4) parsing the tag into one or more tag blocks to create one or more ordered tag blocks, (5) encrypting the one or more ordered tag blocks to obtain one or more ordered tag ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations, (6) concatenating the one or more ordered message ciphertext blocks with the one or more ordered tag ciphertext blocks to obtain final ciphertext, and (7) transmitting the final ciphertext to a second chiplet.

[0463] In some further embodiments, the cryptographic method includes at least one of a) computing a CRC on a concatenation that includes at least the nonce, the message, and the other data, or b) computing a hash with a hash function on a concatenation that includes at least a the nonce, the message, and other data.

[0464] In some further embodiments, the cryptographic method includes at least wherein the encrypting the one or more ordered message blocks to obtain one or more ordered message ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations includes at least a) obtaining one or more substitute values (e.g. encryption circuit **810** with LUT, encryption circuit **2010** with space-saver circuit **2059** with r0 **2017**) corresponding to the one or more ordered message blocks, b) obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given message block within the one or more ordered message blocks, c) performing one or more operations that include at least one or more XOR operations to obtain the ordered message ciphertext blocks, the one or more XOR operations performed at least partly with (i) the one or more substitute values and (ii) the one or more target values. In some further particular embodiments, the obtaining one or more substitute values corresponding to the one or more ordered message blocks includes at least one of a) obtaining the one or more substitute values from a dynamic substitution box (e.g. encryption circuit **810**) or b) computing the one or more substitute values as needed without accessing a dynamic substitution box (e.g. encryption circuit **2010**).

[0465] In some further embodiments, the cryptographic method includes at least wherein encrypting the one or more ordered tag blocks to obtain one or more ordered tag ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations includes at least a) obtaining one or more substitute values (e.g. encryption circuit **810** with LUT, encryption circuit **2010** with space-saver circuit **2059** with r0 **2017**) corresponding to the one or more ordered tag blocks, b) obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given tag block within the one or more ordered tag blocks, and c) performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered tag ciphertext blocks, the one or more XOR operations performed at least partly with (i) the one or more substitute values and (ii) the one or more target values. In some further particular embodiments, the obtaining one or more substitute values corresponding to the one or more ordered tag blocks includes at least one of a) obtaining the one or more substitute values from a dynamic substitution box (e.g. encryption circuit **810**), orb) computing the one or more substitute values as needed without accessing a dynamic substitution box (e.g. encryption circuit **2010**).

[0466] In some further embodiments, the cryptographic method (e.g. method **2500**) further includes at least a) receiving a ciphertext from the second chiplet, b) parsing the ciphertext into at least tag ciphertext and message ciphertext, c) decrypting the tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations; d) decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations, e) computing a tag based on the nonce (e.g. **119**), the message (e.g. **117**) and the other data (e.g. associated data **121**) to obtain a computed tag, f) attempting to verify the message with a comparison of the decrypted tag with the computed tag, g) outputting an error if the verification is unsuccessful, and h) outputting the message if the verification is successful.

[0467] In some further particular embodiments, the cryptographic method further includes at least wherein the decrypting the tag ciphertext to obtain a tag, the decryption including at least one or more operations that include at least one or more XOR operations includes at least a) parsing the tag ciphertext into one or more ordered blocks of tag ciphertext, b) obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table, c) obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given tag ciphertext block within the one or more ordered blocks of tag ciphertext, and d) performing one or more operations that include at least one or more XOR operations to obtain one or more ordered blocks of decrypted tag, the one or more XOR operations being performed with at least (i) the one or more substitute values and (ii) the one or more target values.

[0468] In some further particular embodiments, the cryptographic method further includes at least wherein decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations includes at least a) parsing the message ciphertext into one or more ordered blocks of message ciphertext, b) obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table, c) obtaining, from a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given message ciphertext block within the one or more ordered blocks of message ciphertext, and d) performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered blocks of message, the one or more XOR operations being performed with at least (i) the one or more substitute values and (ii) the one or more target values.

[0469] A cryptographic method (e.g. method **2600**) is performed in a first chiplet. The method includes at least (1) receiving a message for encryption, (2) encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations, (3) computing a tag on a concatenation that includes at least a nonce (e.g. **119**), the message ciphertext (computed above in step 2), and other data (e.g. associated data **121**), (4) encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations, (5) appending the one or more ordered blocks of tag ciphertext to the message ciphertext to obtain final ciphertext, and (6) transmitting the final ciphertext to a second chiplet.

[0470] In some embodiments, the cryptographic method further includes at least wherein the computing a tag on a concatenation that includes at least a nonce, the message ciphertext, and other data includes at least one of a) computing a CRC on a concatenation that includes at least a nonce, the message ciphertext, and other data, or b) computing a hash with a hash function on a concatenation that includes at least a nonce, the message ciphertext, and other data.

[0471] In some embodiments, the cryptographic method further includes at least wherein the encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more

XOR operations includes at least a) parsing the message to obtain at least one or more ordered message blocks, b) obtaining one or more substitute values (e.g. encryption circuit **810** with LUT, encryption circuit **2010** with space-save circuit **2059** with r0 **2017**) corresponding to the one or more ordered message blocks, c) obtaining, via a keystream table (KST), one or more target values associated with one or more position values, a given position value of the one or more position values being associated with a position of a given message block within the one or more ordered message blocks, d) performing one or more operations that include at least one or more XOR operations to obtain one or more ordered message ciphertext blocks, the one or more XOR operations being performed with at least (i) the one or more substitute values and (ii) the one or more target values, and e) concatenating the one or more ordered blocks of message ciphertext to obtain the message ciphertext. In some further particular embodiments the cryptographic method further includes at least wherein the obtaining one or more substitute values corresponding to the one or more ordered message blocks includes at least one of a) obtaining the one or more substitute values from a dynamic substitution box (e.g. encryption circuit **810**), orb) computing the one or more substitute values as needed without accessing a dynamic substitution box (e.g. encryption circuit **2010**).

[0472] In some embodiments, the cryptographic method further includes at least wherein encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations includes at least a) parsing the tag to obtain at least one or more ordered tag blocks, b) obtaining one or more substitute values (e.g. encryption circuit **810** with LUT, encryption circuit **2010** with space-save circuit **2059** with r0 **2017**) corresponding to the one or more ordered tag blocks, c) obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a tag block within the one or more ordered tag blocks, and d) performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered tag ciphertext blocks, the one or more XOR operations performed at least partly with (i) the one or more substitute values and (ii) the one or more target values. In some further particular embodiments, the cryptographic method further includes at least wherein the obtaining one or more substitute values corresponding to the one or more ordered tag blocks includes at least one of a) obtaining the one or more substitute values from a dynamic substitution box (e.g. encryption circuit **810**), orb) computing the one or more substitute values as needed without accessing a dynamic substitution box (e.g. encryption circuit **2010**).

[0473] In some embodiments the cryptographic method (e.g. method **2700**) further includes at least a) receiving a ciphertext from the second chiplet, the ciphertext being a concatenation of a tag ciphertext and a message ciphertext, wherein the tag ciphertext is encryption of a tag previously computed on a concatenation of the message ciphertext, a nonce (e.g. **119**), and other data (e.g. associated data **121**), b) parsing the ciphertext into (i) one or more ordered blocks of tag ciphertext and (ii) the message ciphertext, c) decrypting the one or more ordered blocks of tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations, d) computing a tag based on the message ciphertext, the nonce (e.g. **119**), and the other data (e.g. associated data **121**) to obtain a computed tag, e) attempting verification of the message ciphertext by comparing the decrypted tag with the computed tag, f) outputting an error if the verification is unsuccessful, and g) if the verification is successful: (i) decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations, and (ii) outputting the message.

[0474] In some particular embodiments, the cryptographic method further includes at least wherein the decrypting the one or more ordered blocks of tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations includes at least a) obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table, b) obtaining, from a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given tag ciphertext block within the one or more ordered blocks of tag ciphertext, c) performing one or more operations that include at least one or more XOR operations to obtain one or more ordered tag blocks, the one or more XOR operations performed at least partly with at least (i) the one or more original values corresponding to substitute values and (ii) the one or more target values, and d) concatenating the one or more ordered tag blocks to obtain the decrypted tag.

[0475] In some particular embodiments, the cryptographic method further includes at least wherein decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations includes at least a) parsing the message ciphertext to obtain one or more ordered message ciphertext blocks; b) obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table, c) obtaining, from a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given message ciphertext block within the one or more ordered blocks of message ciphertext, d) performing one or more operations that include at least one or more XOR operations to obtain one or more ordered message blocks, the one or more XOR operations performed at least partly with at least (i) the one or more substitute values and (ii) the one or more target values, and e) concatenating the one or more ordered message blocks to obtain the decrypted message.

[0476] In some embodiments, a chiplet includes at least (1) a receiving circuitry (e.g. Communication sub-chiplet **113**, bus controller **146**, communication bus **156**) configured for receiving a message for encryption, (2) encryption circuitry configured for encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations (e.g. encryption circuit **810**), (3) tag circuitry configured for computing a tag on a concatenation that includes at least a nonce, the message ciphertext, and other data (e.g. CRC **122**), (4) encryption circuitry configured for encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations (e.g. encryption circuit **810**), (5) processing circuitry configured for appending the one or more ordered blocks of tag ciphertext to the message ciphertext to obtain final ciphertext (e.g. secure host **104**, encryption circuit **810**), and (6) transmitting circuitry configured for transmitting the final ciphertext to a second chiplet (e.g. communication sub-chiplet **113**, bus controller **146**, communication bus **156**) (See e.g. method **2600**).

[0477] In some embodiments the chiplet further includes at least (1) receiving circuitry configured for receiving a ciphertext from the second chiplet (e.g. e.g. Communication sub-chiplet **113**, bus controller **146**, communication bus **156**), the ciphertext being a concatenation of a tag ciphertext and a message ciphertext, wherein the tag ciphertext is ciphertext of a tag previously computed on a concatenation of the message ciphertext, a nonce, and other data, (2) parsing circuitry configured for parsing the ciphertext into (i) one or more ordered blocks of tag ciphertext and (ii) the message ciphertext (e.g. secure host **104**, TX circuit **830**), (3) decryption circuitry configured for decrypting the one or more ordered blocks of tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations, (decryption circuit **840**), (4) tag circuitry configured for computing a tag based on the message ciphertext, the nonce, and the other data to obtain a computed tag (CRC **122**), (5) verification circuitry configured for attempting verification of the message ciphertext by comparing the decrypted tag with the computed tag (e.g. secure host **104**), (6) error detecting circuitry configured for outputting a error if the verification is unsuccessful (e.g. secure host **104**), and (7) the verification circuitry configured for if the verification is successful (e.g. secure host **1040**, causing: (i) decryption circuitry (e.g. decryption circuit **840**) configured for decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations, the decryption circuitry configured to be responsive, at least in part to the verification circuitry, and (ii) transmission circuitry (e.g. RX circuit **830**) configured for outputting the message, the decryption circuitry configured to be responsive, at least in part to the verification circuitry (See, e.g. method **2700**).

[0478] It will be understood by those skilled in the art that the terminology used in this specification and in the claims is "open" in the sense that the terminology is open to additional elements not enumerated. For example, the word "includes" should be interpreted to mean "including at least" and so on. Even if "includes at least" is used sometimes and "includes" is used other times, the meaning is the same: includes at least. In addition, articles such as "a" or "the" should be interpreted as not referring to a specific number, such as one, unless explicitly indicated. At times a convention of "at least one of A, B, or C" is used, the intent is that this language includes any combination of A, B, C, including, without limitation, any of A alone, B alone, C alone, A and B, B and C, A and C, all of A, B, and C or any combination of the foregoing, such as for example AABBC, or ABBBCC. The same is indicated by the conventions "one of more of A, B, or C" and "and/or".

[0479] In addition, references to circuits, such as for example TX circuit, RX circuit, encryption circuit, decryption circuit, or LUT space-saver circuit, refer to circuitry for causing a chiplet to perform their respective functions. In some embodiments, these circuits are implemented as sub-chiplets, In some embodiments, these circuits have internal logic. In some embodiments, these circuits include a link to secure host for processing and are associated with executable instructions stored in memory. These executable instructions when executed would cause secure host to perform the respective functions. In some embodiments, these circuits instead contain or are configured to access hard-wired logic. And some embodiments contain a combination of executable instructions and hard-wired logic. In some embodiments, these circuits may be part of a processing device, such as a CPU, a processor, a controller, a field-programmable gate array, or hard-wired logic. These circuits may contain memory, may be configured to access stored memory, may be configured to access remote memory, or may not contain or access memory, dependent on their function.

[0480] Various functional logic blocks, such as for example, a TRNG engine may, in some embodiments, be implemented as circuits. And the above discussion of circuits would be fully applicable.

[0481] Although embodiments have been described in detail, it should be understood that various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention as defined by the appended claims and equivalents thereof.

[0482] The following twenty aspects are additionally possible:

[0483] Aspect 1. A cryptographic method performed in a first chiplet, the method comprising:

- **[0484]** (1) with one or more processing devices, computing a tag on a nonce, a message, and other data;
- **[0485]** (2) parsing the message into one or more message blocks to create one or more ordered message blocks;
- **[0486]** (3) encrypting the one or more ordered message blocks to obtain one or more ordered message ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations;
- **[0487]** (4) parsing the tag into one or more tag blocks to create one or more ordered tag blocks;
- **[0488]** (5) encrypting the one or more ordered tag blocks to obtain one or more ordered tag ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations;
- **[0489]** (6) concatenating the one or more ordered message ciphertext blocks with the one or more ordered tag ciphertext blocks to obtain final ciphertext; and
- **[0490]** (7) transmitting the final ciphertext to a second chiplet.

[0491] Aspect 2. The cryptographic method of aspect 1, wherein computing a tag on a nonce, a message, and other data comprises:

- **[0492]** at least one of:
- **[0493]** computing a CRC on a concatenation that includes at least the nonce, the message, and the other data; or
- **[0494]** computing a hash with a hash function on a concatenation that includes at least a nonce, the message, and other data.

[0495] Aspect 3. The cryptographic method of aspect 1, wherein the encrypting the one or more ordered message blocks to obtain one or more ordered message ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations comprises:

[0496] obtaining one or more substitute values corresponding to the one or more ordered message blocks;

[0497] obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given message block within the one or more ordered message blocks; and

[0498] performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered message ciphertext blocks, the one or more XOR operations performed at least partly with (i) the one or more substitute values and (ii) the one or more target values.

[0499] Aspect 4. The cryptographic method of aspect 3, wherein the obtaining one or more substitute values corresponding to the one or more ordered message blocks comprises:

[0500] at least one of:

[0501] obtaining the one or more substitute values from a dynamic substitution box; or

[0502] computing the one or more substitute values as needed without accessing a dynamic substitution box.

[0503] Aspect 5. The cryptographic method of aspect 1, wherein the encrypting the one or more ordered tag blocks to obtain one or more ordered tag ciphertext blocks, the encryption including at least one or more operations that include at least one or more XOR operations comprises:

[0504] obtaining one or more substitute values corresponding to the one or more ordered tag blocks;

[0505] obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given tag block within the one or more ordered tag blocks; and

[0506] performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered tag ciphertext blocks, the one or more XOR operations performed at least partly with (i) the one or more substitute values and (ii) the one or more target values.

[0507] Aspect 6. The cryptographic method of aspect 5, wherein the obtaining one or more substitute values corresponding to the one or more ordered tag blocks comprises:

[0508] at least one of:

[0509] obtaining the one or more substitute values from a dynamic substitution box; or

[0510] computing the one or more substitute values as needed without accessing a dynamic substitution box.

[0511] Aspect 7. The cryptographic method of aspect 1, further comprising:

[0512] receiving a ciphertext from the second chiplet;

[0513] parsing the ciphertext into at least tag ciphertext and message ciphertext;

[0514] decrypting the tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations;

[0515] decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations;

[0516] computing a tag based on a nonce, the message and other data to obtain a computed tag;

[0517] attempting to verify the message with a comparison of the decrypted tag with the computed tag;

[0518] outputting an error if the verification is unsuccessful; and

[0519] outputting the message if the verification is successful.

[0520] Aspect 8. The cryptographic method of aspect 7, wherein the decrypting the tag ciphertext to obtain a tag, the decryption including at least one or more operations that include at least one or more XOR operations comprises:

[0521] parsing the tag ciphertext into one or more ordered blocks of tag ciphertext;

[0522] obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table;

[0523] obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given tag ciphertext block within the one or more ordered blocks of tag ciphertext; and

[0524] performing one or more operations that include at least one or more XOR operations to obtain one or more ordered blocks of decrypted tag, the one or more XOR operations being performed with at least (i) the one or more original values corresponding to substitute values and (ii) the one or more target values.

[0525] Aspect 9. The cryptographic method of aspect 7, wherein decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations comprises:

[0526] parsing the message ciphertext into one or more ordered blocks of message ciphertext;

[0527] obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table;

[0528] obtaining, from a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given message ciphertext block within the one or more ordered blocks of message ciphertext; and

[0529] performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered blocks of message, the one or more XOR operations being performed with at least (i) the one or more original values corresponding to substitute values and (ii) the one or more target values.

[0530] Aspect 10. A cryptographic method performed in a first chiplet, the method comprising:

[0531] (1) receiving a message for encryption;

[0532] (2) encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations;

[0533] (3) computing a tag on a concatenation that includes at least a nonce, the message ciphertext, and other data;

[0534] (4) encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations;

[0535] (5) appending the one or more ordered blocks of tag ciphertext to the message ciphertext to obtain final ciphertext; and

[0536] (6) transmitting the final ciphertext to a second chiplet.

[0537] Aspect 11. The cryptographic method of aspect 10, wherein the computing a tag on a concatenation that includes at least a nonce, the message ciphertext, and other data comprises:

[0538] at least one of:

[0539] computing a CRC on a concatenation that includes at least a nonce, the message ciphertext, and other data; or

[0540] computing a hash with a hash function on a concatenation that includes at least a nonce, the message ciphertext, and other data.

[0541] Aspect 12. The cryptographic method of aspect 10, wherein the encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations comprises:

[0542] parsing the message to obtain at least one or more ordered message blocks;

[0543] obtaining one or more substitute values corresponding to the one or more ordered message blocks;

[0544] obtaining, via a keystream table (KST), one or more target values associated with one or more position values, a given position value of the one or more position values being associated with a position of a given message block within the one or more ordered message blocks;

[0545] performing one or more operations that include at least one or more XOR operations to obtain one or more ordered message ciphertext blocks, the one or more XOR operations being performed with at least (i) the one or more substitute values and (ii) the one or more target values; and

[0546] concatenating the one or more ordered blocks of message ciphertext to obtain the message ciphertext.

[0547] Aspect 13. The cryptographic method of aspect 12, wherein the obtaining one or more substitute values corresponding to the one or more ordered message blocks comprises:

[0548] at least one of:

[0549] obtaining the one or more substitute values from a dynamic substitution box; or

[0550] computing the one or more substitute values as needed without accessing a dynamic substitution box.

[0551] Aspect 14. The cryptographic method of aspect 10, wherein encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations comprises:

[0552] parsing the tag to obtain at least one or more ordered tag blocks;

[0553] obtaining one or more substitute values corresponding to the one or more ordered tag blocks;

[0554] obtaining, via a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a tag block within the one or more ordered tag blocks; and

[0555] performing one or more operations that include at least one or more XOR operations to obtain the one or more ordered tag ciphertext blocks, the one or more XOR operations performed at least partly with (i) the one or more substitute values and (ii) the one or more target values.

[0556] Aspect 15. The cryptographic method of aspect 14, wherein the obtaining one or more substitute values corresponding to the one or more ordered tag blocks comprises:

[0557] at least one of:

[0558] obtaining the one or more substitute values from a dynamic substitution box; or

[0559] computing the one or more substitute values as needed without accessing a dynamic substitution box.

[0560] Aspect 16. The cryptographic method of aspect 10, further comprising:

[0561] receiving a ciphertext from the second chiplet, the ciphertext being a concatenation of a tag ciphertext and a message ciphertext, wherein the tag ciphertext is ciphertext of a tag previously computed on a concatenation of the message ciphertext, a nonce, and other data;

[0562] parsing the ciphertext into (i) one or more ordered blocks of tag ciphertext and (ii) the message ciphertext;

[0563] decrypting the one or more ordered blocks of tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations;

[0564] computing a tag based on the message ciphertext, the nonce, and the other data to obtain a computed tag;

[0565] attempting verification of the message ciphertext by comparing the decrypted tag with the computed tag;

[0566] outputting an error if the verification is unsuccessful; and

[0567] if the verification is successful:

[0568] (i) decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations; and

[0569] (ii) outputting the message.

[0570] Aspect 17. The cryptographic method of aspect 16, wherein the decrypting the one or more ordered blocks of tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations comprises:

[0571] obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table;

[0572] obtaining, from a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given tag ciphertext block within the one or more ordered blocks of tag ciphertext;

[0573] performing one or more operations that include at least one or more XOR operations to obtain one or more ordered tag blocks, the one or more XOR operations performed at least partly the with at least (i) the one or more original values corresponding to substitute values and (ii) the one or more target values; and

[0574] concatenating the one or more ordered tag blocks to obtain the decrypted tag.

[0575] Aspect 18. The cryptographic method of aspect 16, wherein decrypting the message ciphertext to obtain a message, the decryption including at least one or more operations that include at least one or more XOR operations comprises:

[0576] parsing the message ciphertext to obtain one or more ordered message ciphertext blocks; obtaining, from an inverse lookup table, one or more original values using one or more substitute values as keys into the inverse lookup table;

[0577] obtaining, from a keystream table (KST), one or more target values corresponding to one or more position values, a given position value of the one or more position values being associated with a position of a given message ciphertext block within the one or more ordered blocks of message ciphertext;

[0578] performing one or more operations that include at least one or more XOR operations to obtain one or more ordered message blocks, the one or more XOR operations performed at least partly with at least (i) the one or more original values corresponding to substitute values and (ii) the one or more target values; and

[0579] concatenating the one or more ordered message blocks to obtain the message

[0580] Aspect 19. A chiplet comprising:

[0581] (1) a receiving circuitry configured for receiving a message for encryption;

[0582] (2) encryption circuitry configured for encrypting the message to obtain message ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations;

[0583] (3) tag circuitry configured for computing a tag on a concatenation that includes at least a nonce, the message ciphertext, and other data;

[0584] (4) encryption circuitry configured for encrypting the tag to obtain one or more ordered blocks of tag ciphertext, the encryption including at least one or more operations that include at least one or more XOR operations;

[0585] (5) processing circuitry configured for appending the one or more ordered blocks of tag ciphertext to the message ciphertext to obtain final ciphertext; and

[0586] (6) transmitting circuitry configured for transmitting the final ciphertext to a second chiplet.

[0587] Aspect 20. The chiplet of aspect 19, further comprising:

[0588] (1) receiving circuitry configured for receiving a ciphertext from the second chiplet, the ciphertext being a concatenation of a tag ciphertext and a message ciphertext, wherein the tag ciphertext is ciphertext of a tag previously computed on a concatenation of the message ciphertext, a nonce, and other data;

[0589] (2) parsing circuitry configured for parsing the ciphertext into (i) one or more ordered blocks of tag ciphertext and (ii) the message ciphertext;

[0590] (3) decrypting circuitry configured for decrypting the one or more ordered blocks of tag ciphertext to obtain a decrypted tag, the decryption including at least one or more operations that include at least one or more XOR operations;

[0591] (4) tag circuitry configured for computing a tag based on the message ciphertext, the nonce, and the other data to obtain a computed tag;

[0592] (5) verification circuitry configured for attempting verification of the message ciphertext by comparing the decrypted tag with the computed tag;

[0593] (6) error detecting circuitry configured for outputting an error if the verification is unsuccessful; and

[0594] (7) the verification circuitry configured for if the verification is successful, causing:

[0595] (i) decryption circuitry configured for decrypting the message ciphertext to obtain a plaintext message, the decrypting including at least one or more operations that include at least one or more XOR operations, the decryption circuitry configured to be responsive, at least in part to the verification circuitry; and

[0596] (ii) transmission circuitry configured for outputting the message, the decryption circuitry configured to be responsive, at least in part to the verification circuitry.

We claim:

1. A cryptographic method performed at least in part at a first chiplet, the method comprising:

(1) with the first chiplet, parsing a message into at least one or more message blocks;

(2) dynamically generating at least a first target value that is associated with at least a first key;

(3) dynamically generating at least a second target value that is associated with at least a second key;

(4) encrypting at least one message block of the at least one or more message blocks to generate at least some ciphertext, the encryption being performed with at least one operation that includes at least one XOR operation, the at least one XOR operation being performed at least in part with the first target value and with at least the second target value, the first target value and the second target value being accessed at partly via the first and second keys, respectively; and

(5) with at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet.

2. The cryptographic method of claim **1**, wherein:

the first key is the message block of the one or more message blocks; and

the first target value is at least one of a random number or a pseudo-random number accessed as a substitute for the first key.

3. The cryptographic method of claim **1**, wherein:

the one or more message blocks are one or more ordered message blocks;

the second key is a numerical index value associated with a position of the at least one message block within the one or more ordered message blocks; and

the second target value is at least one of a random number or a pseudo-random number.

4. The cryptographic method of claim **1**, wherein dynamically generating at least a first target value that is associated with at least a first key comprises:

generating a dynamic substitution box that includes at least (i) the first key and (ii) the first target value, the generating the dynamic substitution box including at least:

a) generating a plurality of keys that include the first key, including at least generating the plurality of keys to include at least respective numerical representations of the one or more message blocks; and

b) generating a plurality of target values, including at least generating the first target value as a substitute value for a numerical representation associated with the first key.

5. The cryptographic method of claim **4**, further comprising:

sorting the plurality of keys in the dynamic substitution table, the sorting being based on at least in part on the respective numerical representations of the plurality of keys; and

accessing the first target value in the dynamic substitution box by locating the first key, the locating being performed at least in part by searching the sorted numerical representations of the plurality of keys to locate the numerical representation of the first key.

6. The cryptographic method of claim **1**, wherein dynamically generating at least a second target value that is associated with at least a second key comprises:

generating a lookup table that includes at least (i) the second key and (ii) the second target value, the generating the lookup table including at least:

a) generating a plurality of keys that include at least the second key, the plurality of keys including at least respective numerical index values; and

b) generating a plurality of target values that include at least the second target value, respective ones of the plurality of target values being accessible in the lookup table at least in part via the respective numerical index values of the plurality of keys.

7. The cryptographic method of claim **6**, further comprising:

accessing the second target value in the lookup table by locating the second key, the locating being performed at least in part by searching the respective numerical index values of the plurality of keys to locate a numerical index value associated with the second key.

8. The cryptographic method of claim **1**, wherein generating the first target value includes at least generating a first random number with a true random number generator and wherein generating the second target value includes at least generating a second random number with the true random number generator.

9. The cryptographic method of claim **8**,

wherein generating the first target value additionally includes generating the first target value based at least in part on an output of a pseudo-random number generator seeded with a seed that includes at least the first random number; and

wherein generating the second target value additionally includes generating the second target value based at least in part on an output of a pseudo-random number generator seeded with a seed that includes at least the second random number.

10. The cryptographic method of claim **1**, further comprising:

generating a tag based at least in part on the message, a nonce value, and some additional data; and

concatenating the tag with at least the message block of the one or more message blocks; and

wherein the encrypting at least a message block of the at the one or more message blocks further includes encrypting at least the concatenation of the tag with the at least one message block.

11. The cryptographic method of claim **1**, wherein the method is performed with a first chiplet that is part of a resource constrained device.

12. The cryptographic method of claim **1**, wherein the dynamically generating at least a first target value that is associated with at least a first key comprises:

dynamically generating at least a first substitute value for the first key and wherein the generating the first substitute value does not include generating a lookup table containing the first substitute value.

13. The cryptographic method of claim **1**, wherein the with at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet comprises:

at least one of:

transmitting in a no-delay half-duplex mode in which the first chiplet encrypts a message block of the one or more message blocks while waiting for a message from the second chiplet;

transmitting in a space-saver mode in which the first chiplet saves memory resources by generating the first target value without generating a dynamic substitution box;

transmitting in a two-key encryption mode in which a first security configuration is used for transmitting from the first chiplet to the second chiplet and a second security configuration is used for transmitting from the second chiplet to the first chiplet;

transmitting in a two-key space-saver mode in which the security configuration is a combination of the space-saver mode and the two-key encryption mode; or

transmitting in a high performance mode that utilize data compression and data decompression.

14. A cryptographic method performed at least in part at a second chiplet, the method comprising:

(1) dynamically generating a first lookup table that includes a plurality of first target values and a plurality of first keys, a given first target value of the plurality of first lookup values being obtainable based on corresponding first key of the plurality of first keys, and wherein the first lookup table is at least one of usable or configurable as an inverse lookup table for obtaining the corresponding first key based at least in part on the given first target value;

(2) dynamically generating at least a second lookup table that includes a plurality of second target values and a plurality of second keys, a given second target value of the plurality of second target values being obtainable based on a corresponding second key of the plurality of second keys;

(3) decrypting at least one ciphertext block of one or more ciphertext blocks to generate at least some plaintext, the decryption being performed at least partly with one or more operations that include at least one or more XOR operations, the one or more XOR operations performed at least in part with the corresponding first

key obtained at least partly via the given first target value and with at least the given second target value obtained at least partly via the corresponding second key;

(4) verifying the at least some plaintext; and

(5) outputting the at least some plaintext responsive to a successful verification of the plaintext.

15. The cryptographic method of claim **14**, wherein the at least one XOR operation reverses at least one previous XOR operation performed at the first chiplet during encryption of the one or more ciphertext blocks.

16. The cryptographic method of claim **14**, further comprising:

receiving ciphertext at the second chiplet transmitted from a first chiplet; and

parsing the ciphertext into the one or more ciphertext blocks.

17. The cryptographic method of claim **14**, wherein the verifying the at least some plaintext comprises:

separating the at least some plaintext into a first tag and at least a portion of a message;

computing a second tag based at least in part on the at least a portion of a message, on a nonce, and on additional data;

comparing the first tag and the second tag; and

if the first tag and the second tag do not match issuing an error message indicating that verification of the at least some plaintext has failed.

18. The cryptographic method of claim **14**,

wherein the first target values are at least one of random or pseudo-random numbers; and

wherein the first lookup table is usable as an inverse lookup table by at least:

selecting a block of ciphertext of the one or more ciphertext blocks, the block of ciphertext including at least a numerical value;

searching the target values of the first lookup table for a particular target value that matches the numerical value of the selected block of ciphertext, the searching performed with at least a linear search algorithm; and

based at least in part on the particular target value obtaining a first key of the plurality that corresponds in the first lookup table with the particular target value.

19. The cryptographic method of claim **14**,

wherein the first target values of the plurality are at least one of random or pseudo-random numbers; and

wherein the first lookup table is configurable and usable as an inverse lookup table by at least:

sorting the plurality of first target values;

selecting a block of ciphertext of the one or more ciphertext blocks, the block of ciphertext including at least a numerical value;

searching the target values of the first lookup table for a particular target value that matches the numerical value associated with the selected block of ciphertext, the search performed with at least a non-linear search algorithm; and

based at least in part on the particular target value obtaining a first key of the plurality that is associated in the first lookup table with the particular target value.

20. A cryptographic method performed at least in part at a first chiplet based in a resource-constrained computing device, the method comprising:

with the first chiplet, parsing a message into at least one or more message blocks;

dynamically generating at least a first target value that is associated with at least a first key;

dynamically generating at least a second target value that is associated with at least a second key;

encrypting at least a message block of the at least one or more message blocks to generate at least some ciphertext, the encryption being performed with at least one or more operations that include one or more XOR operations, the at least one XOR operation being performed at least in part with the first target value and with at least the second target value, the first target value and the second target value being accessed at partly via the first and second keys, respectively;

with at least one processing device associated with the first chiplet, transmitting the at least some ciphertext to a second chiplet;

receiving ciphertext for decryption and transmitting the ciphertext to another computing device for decryption.

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