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(54) **SYSTEM AND METHODS FOR MESSAGE REDUNDANCY**

(56) **References Cited**

U.S. PATENT DOCUMENTS

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4,809,362 A 2/1989 Claus H04J 14/0227
370/407

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6,098,155 A 8/2000 Chong, Jr.
(Continued)

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FOREIGN PATENT DOCUMENTS

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GB 2515501 A 12/2014
WO 2004056043 A1 7/2004

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OTHER PUBLICATIONS

United States Patent & Trademark Office (USPTO), Non-Final
Rejection to U.S. Appl. No. 15/074,113, filed Dec. 27, 2017.

(Continued)

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(57) **ABSTRACT**

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H04L 51/23 (2022.01)
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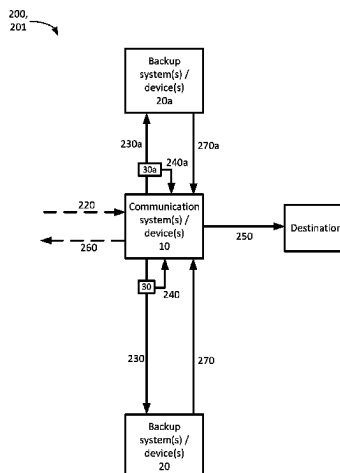
Systems, methods, and devices for communication are described. A communication system includes a first communication device configured to communicate with a backup device and a destination; and a first tapping device for monitoring messages sent over a first communication link between the first communication device and the backup device. The first communication device includes at least one processor configured to: before sending a first message destined for the destination, send a backup message corresponding to the first message over the communication link for backup at the backup device; and upon confirmation of a tap copy of the backup message from the first tapping device, send the first message to the destination.

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See application file for complete search history.

37 Claims, 4 Drawing Sheets



Related U.S. Application Data								
(60)	Provisional application No. 62/136,164, filed on Mar. 20, 2015.			2011/0235503	A1	9/2011	Chen H04L 41/0846 370/219	
				2012/0215854	A1 *	8/2012	Keast H04L 51/224 709/206	
				2013/0208630	A1	8/2013	Bobrek H04L 67/12 370/276	
(51)	Int. Cl. <i>H04L 43/087</i> (2022.01) <i>H04L 43/10</i> (2022.01) <i>H04L 43/12</i> (2022.01) <i>H04L 51/234</i> (2022.01)			2013/0304809	A1	11/2013	Fletcher H04L 69/161 709/203	
				2013/0304892	A1	11/2013	Afergan H04L 67/01 709/223	
				2013/0340100	A1 *	12/2013	Moskowitz H04L 65/61 726/30	
				2014/0073357	A1 *	3/2014	Johnson G06Q 30/02 455/456.3	
(52)	U.S. Cl. CPC <i>H04L 43/0817</i> (2013.01); <i>H04L 43/087</i> (2013.01); <i>H04L 43/10</i> (2013.01)			2014/0215280	A1	7/2014	Li et al. H04L 67/1001	
				2014/0330976	A1 *	11/2014	van Bommel H04L 67/1001 709/226	
(56)	References Cited							
	U.S. PATENT DOCUMENTS							
	6,643,267	B1	11/2003	Karia H04L 43/0852 370/252	2016/0078068	A1	3/2016	Agrawal G06F 16/174 707/692
	6,757,248	B1	6/2004	Li H04L 1/188 370/235	2017/0230326	A1	8/2017	Eidelson H04L 51/046
	8,131,967	B2	3/2012	Lemke G06F 13/4059 711/167	2018/0183832	A1	6/2018	Chang H04L 63/1416
	8,489,670	B1	7/2013	Fletcher H04L 69/16 709/203	2019/0089791	A1	3/2019	Hammer H04M 15/41
	8,682,954	B2	3/2014	Harpaz G06F 11/2041 709/219	2019/0182570	A1	6/2019	Hushchyn H04B 10/2507
	9,397,881	B1	7/2016	Fritz H04L 41/0663	2019/0288960	A1	9/2019	Huang H04L 49/201
	10,362,131	B1	7/2019	Robbins G06F 11/2041	2020/0014566	A1	1/2020	Ahmed H04B 10/61
	10,455,041	B2	10/2019	Nigam H04L 67/1008	2020/0195530	A1	6/2020	Pang H04L 43/026
	2002/0064132	A1	5/2002	Akyol H04L 41/0803 370/254	OTHER PUBLICATIONS			
	2003/0031175	A1	2/2003	Hayashi H04L 1/1809 370/390	United States Patent & Trademark Office (USPTO), Final Rejection to U.S. Appl. No. 15/074,113, filed Sep. 4, 2018.			
	2006/0092933	A1	5/2006	Astley H04L 67/2814 370/389	United States Patent & Trademark Office (USPTO), Final Rejection to U.S. Appl. No. 15/074,113, filed Nov. 18, 2021.			
	2007/0064917	A1	3/2007	Matityahu et al.	United States Patent & Trademark Office (USPTO), Final Rejection to U.S. Appl. No. 15/074,113, filed Apr. 29, 2020.			
	2008/0002694	A1 *	1/2008	Brahmaroutu G06F 11/1456 370/392	United States Patent & Trademark Office (USPTO), Non-Final Rejection to U.S. Appl. No. 15/074,113, filed Dec. 24, 2020.			
	2009/0204981	A1	8/2009	Karino G06F 11/2097 719/328	Canadian Intellectual Property Office, Office Action for Application CA 2,980,196 dated Jan. 30, 2024.			
	2009/0233625	A1	9/2009	Ferguson H04W 64/00 455/456.5	Supplementary European Search Report issued in European Application No. 16767574, dated Aug. 6, 2018.			
	2011/0184913	A1	7/2011	Hayden G06F 11/2097 707/652	WIPO, International Search Report and Written Opinion for PCT Application No. PCT/CA2016/050306 dated May 13, 2016.			
				* cited by examiner				

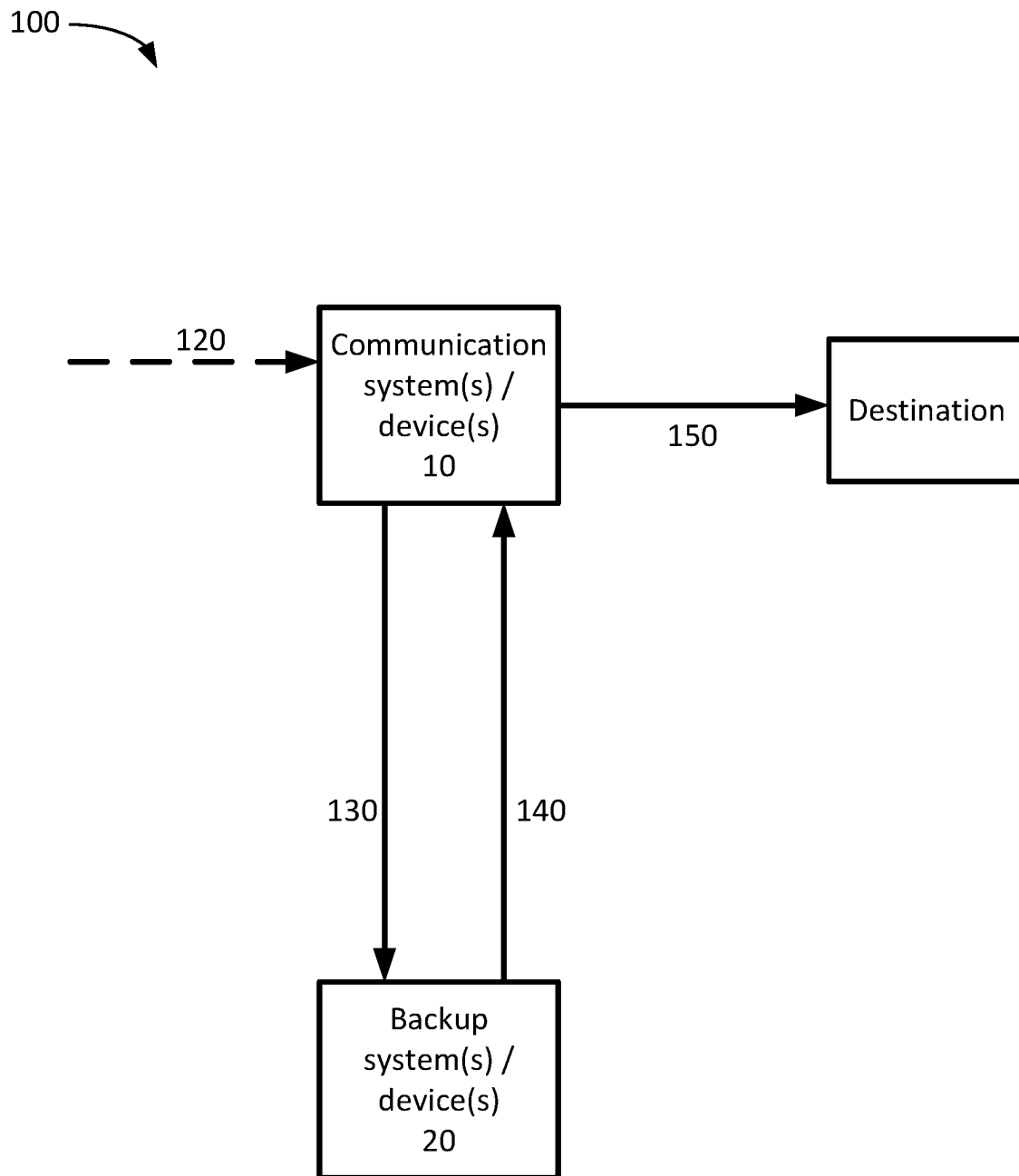


FIG. 1

200,
201


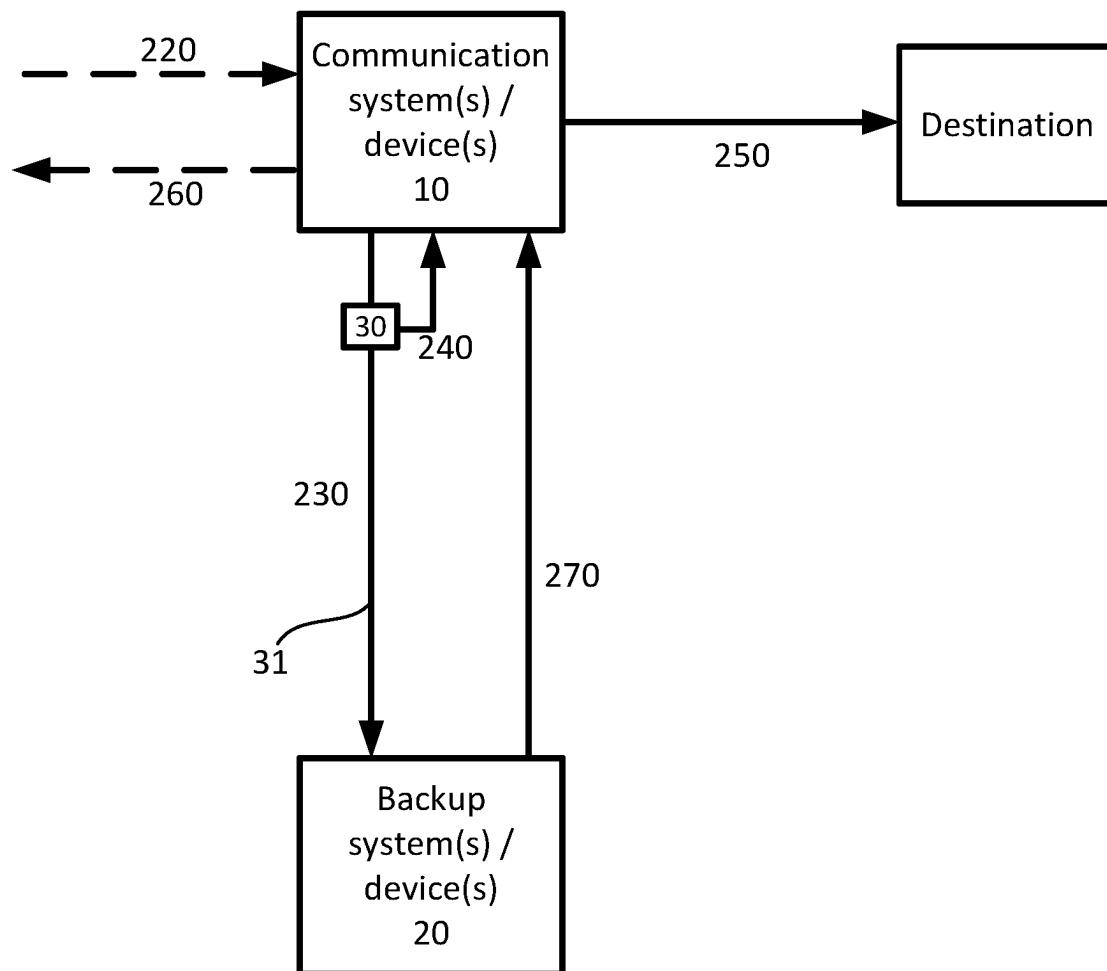



FIG. 2

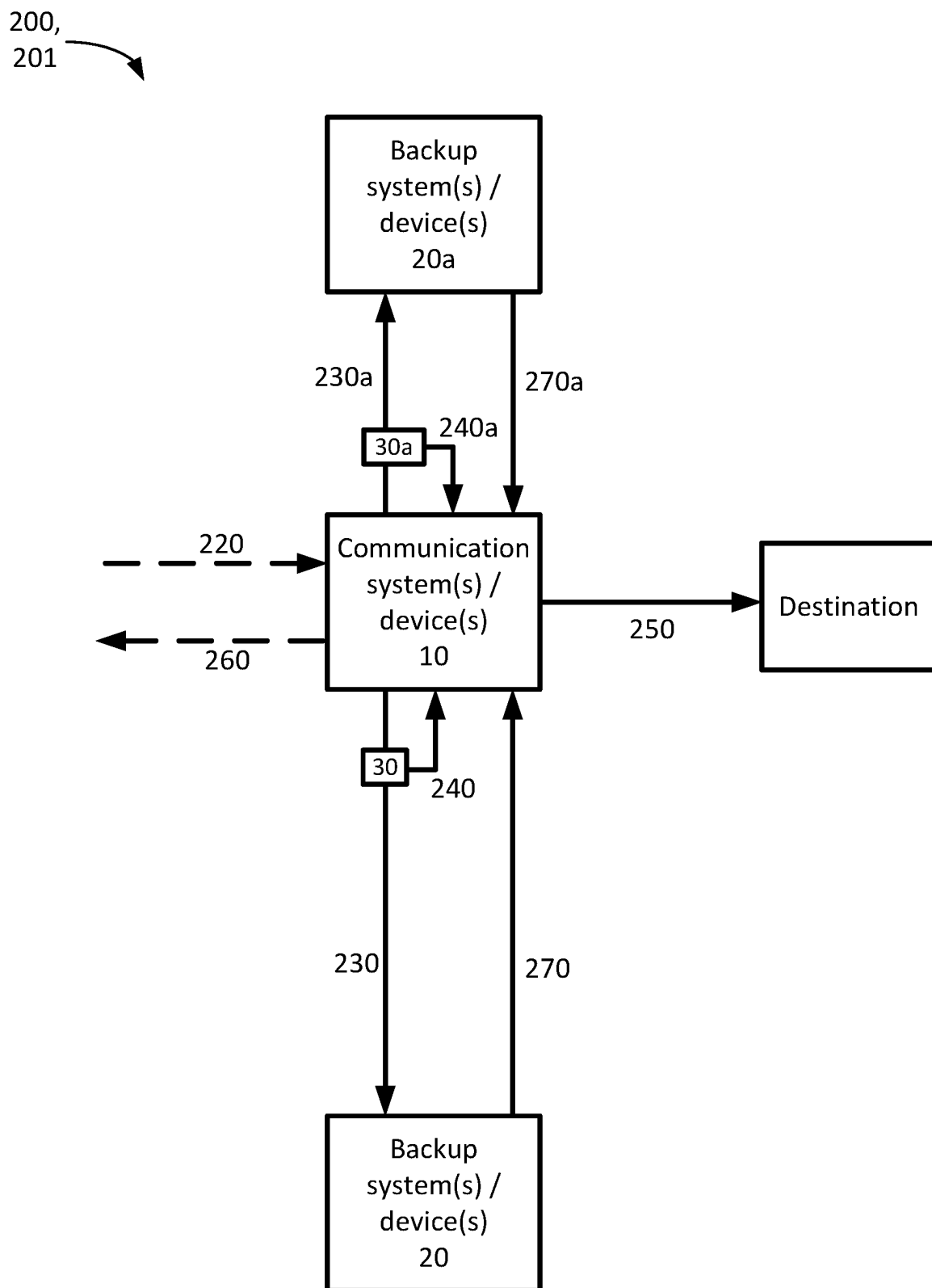


FIG. 3

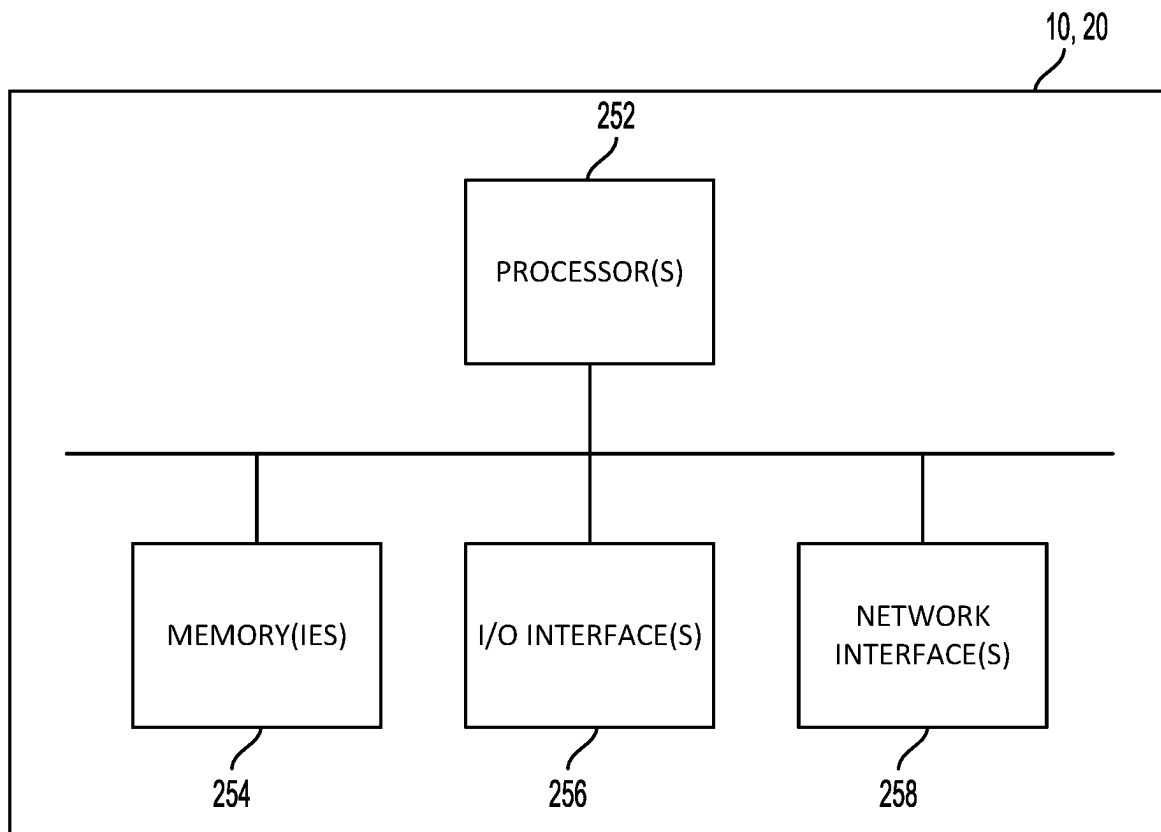


FIG. 4

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SYSTEM AND METHODS FOR MESSAGE REDUNDANCY

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Ser. No. 15/074,113 filed on Mar. 18, 2016, which claims all benefit, including priority to U.S. Provisional Patent Application No. 62/136,164, filed Mar. 20, 2015, and entitled "SYSTEM AND METHODS FOR MESSAGE REDUNDANCY", the entirety of which is hereby incorporated by reference.

FIELD

The present disclosure relates generally to data redundancy and particularly to systems, methods, devices and computer-readable media for the redundancy in data to be communicated over communication links or networks.

BACKGROUND

In certain industries, systems may be required to transmit information to another device or location with a high degree of certainty. Backup systems and networks have been used to increase the chances of a loss-less recovery.

SUMMARY

In an aspect, there is provided a communication system. The communication system includes a first communication device configured to communicate with a backup device and a destination; and a first tapping device for monitoring messages sent over a first communication link between the first communication device and the backup device. The first communication device includes at least one processor configured to: before sending a first message destined for the destination, send a backup message corresponding to the first message over the communication link for backup at the backup device; and upon confirmation of a tap copy of the backup message from the first tapping device, send the first message to the destination.

In another aspect, there is provided a communication device. The communication device includes at least one processor configured to: before sending a first message destined for a destination, send a backup message corresponding to the first message over a communication link for backup at a backup device; and upon confirmation of a tap copy of the backup message from a tapping device on the communication link, send the first message to the destination.

In another aspect, there is provided a communication method. The method includes: before sending, from a communication device, a first message destined for a destination, sending a backup message corresponding to the first message from the communication device to a backup device over a communication link; and upon confirmation of a tap copy of the backup message from a tapping device on the communication link, send the first message to the destination.

Many further features and combinations thereof concerning the present improvements will appear to those skilled in the art following a reading of the present disclosure.

DESCRIPTION OF THE FIGURES

Reference will now be made to the drawings, which show by way of example embodiments of the present disclosure.

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FIGS. 1, 2 and 3 show aspects of example systems and example communication flows in accordance with various aspects of the disclosure.

FIG. 4 shows a schematic diagram showing example devices in accordance with various aspects of the disclosure.

DESCRIPTION OF EXAMPLE EMBODIMENTS

In a data-driven world, reliability can be an important aspect of data communication systems. In some embodiments, backup systems for storage or redundant communication can be used to ensure a high degree of certainty that a data message will be transmitted, stored, and/or processed and/or will otherwise persist in some form and/or location.

FIG. 1 shows aspects of an example system 100 and flowchart illustrating a backup process. The system includes one or more communication device(s) and/or system(s) 10 for communicating messages to a destination.

At 120, the communication device(s) 10 may optionally receive instructions and/or data for transmission to a destination. In some examples, the communication device(s) 10 may generate the instructions/data itself or may translate, re-package or otherwise manipulate received instructions/data for transmission.

With a message including the received/generated instructions and/or data, the communication device(s) 10 can be configured to send 130 a backup copy of the message to a backup system/device 20.

Upon receiving the backup copy, the backup system/device 20 can be configured to verify, store and/or otherwise process the backup copy and at 140, send an acknowledgement message back to the communication device(s) 10. In some embodiments, the acknowledgement message includes an identifier (e.g. a sequence number), a portion, or some indication of the backup message to which the acknowledgement relates.

Upon receipt of the acknowledgement message, the communication device(s) 10 can, at 150, send the message to the destination. In this manner, before sending the message to the destination, the system ensures that a backup copy exists in the event there is a failure of the communication device(s) 10.

In some embodiments, the system 100 above may cause a delay between the time data/instructions are received (120) or generated, and the time the message is sent 150 to the destination. In some examples, the delay may include latencies cause by creating the backup message, the transmission latency of sending 130 the backup message from the communication device(s) 10 to the backup system 20, the execution latency for the backup system 20 to process the backup message, the latency of sending 140 the acknowledgement message from the backup system 20 to the communication device(s) 10, and the execution latency for the communication device(s) 10 to process the acknowledgement. While, in some examples, the execution latencies may be small, the transmission latencies (e.g. 130, 140) may be significant depending on the physical distance between the communication device(s) 10 and the backup system 20.

The total delay/latency required to create a backup may negatively impact the performance of the system 100. In some situations, such as those involving time-sensitive communications, these delays are undesirable and may be unacceptable.

In some examples, the backup system 20 may be in a remote location to ensure that a regional catastrophe does not disable or cause a failure of both the primary commu-

nication device(s) **10** and the backup device(s) **20**. However, the greater distances of remote locations may exasperate the transmission latencies.

FIG. 2 shows aspects of another example system **200**, and flowchart **201** illustrating an example communication process.

The communication device **10** can be a device configured for data communication with a backup system/device **20** and a destination. In some embodiments, the communication device **10** can be a router, switch or other device configured to receive data and/or instructions from another device or system for communicating with the backup system/device **20** and the destination.

FIG. 4 is a schematic diagram showing aspects of an example communication system/device **10**, and/or backup system/device **20**. While the example in FIG. 4 shows a single device, in some embodiments, the communication device **10**, **20** can include or consist of multiple devices and in some examples, can be physically and/or logically grouped as a system or any other arrangement.

Without limiting the foregoing, reference to a communication device or system **10** should not be interpreted as limited to a single device, but may include multiple devices and/or one or more systems having the same components and/or configured to perform the same functions as described with reference to a communication device **10**. This applies similarly to references to a backup system or device.

In some examples, the backup system/device(s) **20** may include the same or similar components to the primary communication device(s) **10**. In some examples, the backup system/device(s) **20** can be configured to perform the same function(s) as a communication device **10**, or may be another instance of a primary communication device **10** configured to generate and/or receive instructions from another device or system for communicating with one or more destination(s) and/or another backup system/device **20**.

In some example embodiments, communication devices **10** and/or backup device **20** may include one or more processor(s) **252** connected to one or more memory(ies) **254** or other temporary and/or persistent storage memory device(s). The processor(s) may be connected to one or more network interface(s) **258** configured to transmit and/or receive data messages over a wired (optical fiber, copper line, etc.), wireless (Wi-Fi, radio, microwave, etc.), and/or any other interface. The processor(s), network interface(s) and/or other aspects of the device(s) **10**, **20** may include any suitable hardware structure for generating signals for wired or wireless transmission and/or processing received signals. The processor(s), network interface(s) and/or other aspects of the device(s) **10**, **20** may include modules or may be otherwise configured to interpret, translate, encapsulate, cache, queue, re-order, encode/decode, encrypt/decrypt, or otherwise process or generate messages suitable for transmitting to the destination or between the communication device **10** and the backup device **20**.

The memory(ies) **254** may be accessible by the processor(s) to access, receive and/or store data. The memory(ies) **254** may include a main memory, such as a high speed Random Access Memory (RAM), an auxiliary storage unit, such as a hard disk, flash memory, registers and/or a magnetic tape drive. The memory(ies) **254** may include any other type of memory, such as a Read-Only Memory (ROM), Erasable Programmable Read-Only Memory (EPROM), electrically-erasable programmable read-only memory (EEPROM), Ferroelectric RAM (FRAM), or optical storage media such as a Blu-ray Disc™, videodisc and a

compact disc. In an embodiment, the memory may be used to buffer data and/or instructions. The processor(s) may access the memory(ies) to retrieve data or instructions.

The processor(s) **252** may include any device that can perform operations on data. Examples include a central processing unit (CPU), a front-end processor, a microprocessor, a field programmable gate array (FPGA), a reconfigurable processor, a digital signal processor, a network processor, an integrated circuit, or any other processing device and/or any combination thereof. Applications may be running on the processor and may be configured to perform various tasks including at least aspects of the methods described herein. The processor(s) may be configured to perform one or more aspects of the methods and processes described herein.

The device(s) **10**, **20** may include input/output devices and/or input/output interface(s) **256** for input/output devices such as built-in or peripheral devices such as displays, touchscreens, keyboards, sensors, input mechanisms, actuators, data storage devices and the like.

Referring to FIG. 2, at **220**, the communication device **10** may be optionally configured to receive, from a source, information to be communication to the destination. The information may include instructions and/or data. In some embodiments, the communication device **10** may be configured to interpret, translate, encapsulate, cache, queue, re-order, encode/decode, encrypt/decrypt, or otherwise process or generate messages suitable for transmitting to the destination or the backup device **20** based on and/or including the information received from the source.

In some embodiments, the communication device **10** may be configured to generate messages for transmitting to the destination and backup device **20** its own information (e.g. data or instructions) or information accessed or generated in conjunction with another system or device.

At **230**, before sending the message to the destination, the communication device **10** can be configured to send a backup message to the backup device **20**. In some examples, the backup message can include a copy of the message. For examples, the backup message can be identical copy of the message, or may additional headers or other information and/or metadata.

In some examples, the backup message may not be a copy of the message, but may include data and/or instructions which may be used by the backup **20** or other device to recreate the message or may identify the instruction, intention and/or information in the original message such that a similar message suitable for sending to the destination.

For example, when a message destined for a destination includes a trade request from client identifier A to purchase **100** shares of a stock B from venue C at price D, the backup message can be: an exact copy of the message, a message including all the details of the original message but perhaps not in the same format/encoding/etc., or a message including data which simply indicates that the original was a request from client identifier A to purchase **100** shares of stock B. In the last example, the backup message does not contain details regarding price or venue but includes enough information such that a new substitute message can be created which satisfies the intention of the original request to purchase **100** shares of stock B for a client associated with client identifier A.

In some embodiments, the backup message may include or may consist of an identifier such as a sequence number associated with the message. In some such examples, the sequence number may not contain information for recreating the message but can identify dropped or unsuccessfully

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transmitted message(s) should an error or transmission problem occur when the message is transmitted to the destination.

In some embodiments, the backup message can be sent to the backup device **20** over a communication link **31**. In some examples, the communication link **31** may include a direct communication link such as a direct end-to-end optical fiber, copper or other physical connection to the backup system. In some examples, the communication link **31** may include a wireless communication link, a direct line of sight microwave and/or a laser communication link. In some embodiments, the communication link **31** can include any mechanism or medium for communicating data from a source device to a destination device.

In some examples, the communication link is a single or otherwise undivided or unbroken communication link between the first communication device and the backup device. For example, an optical fiber connection with no intermediate connector or network device.

In other embodiments, the communication link **31** may include one or more dedicated lines and/or networks. In some examples, the dedicated line or network may utilize or include one or more redundancy paths, devices and/or lossless failover mechanisms. The dedicated line and/or network may include a guaranteed level of service. In some embodiments, the communication link **31** may include any combination of private and/or public, wired or wireless networks.

The system **200**, **10** can include a tapping device **30** for monitoring messages sent over the communication link **31**. In some embodiments, the tapping device **30** can be a network tap such as a fiber optic or copper tap.

In some embodiments, the tapping device **30** may be a passive device connected to the communication link **31** which allows signals from the communication device **10** to the backup device **20** to pass through uninterrupted while monitoring the content of those signals. For example, a passive optical tap may redirect a small portion of the light signals travelling along an optical fiber connection from the communication device **10** to the backup device **20**. In some examples, the tapping device **30** can include an optical tap, a copper tap or any other passive tapping device.

In some examples, the tapping device **30** can include an amplifier or can be otherwise configured to amplify the signals tapped from the communication link **31**.

In some embodiments, the tapping device **30** may include a device that monitoring messages sent over the communication link by receiving signals from the communication device **10** and then generates identical signals for continuing their transmission to the backup device **20**. In some examples, the tapping device **30** may be configured to allow the signals to pass through un-hindered in the event the power to the tapping device **30** is lost and/or any other failure occurs.

In some embodiments, the tapping device **30** may be positioned on the communication link proximate or relatively close to the communication device **10**. In some examples, by positioning the tapping device close to the communication device **10**, the transmission time of a message from the communication device to the tapping device is shorter than if the tapping device was positioned further along the communication link. For example, the tapping device can be positioned at a location on the communication link that closer to the communication device **10** than to the backup device.

In some examples, the tapping device **30** may be positioned within the first 10%, 25% or 50% of the length/

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distance of the communication link as measured from the communication device **10** to the backup device.

In some embodiments, the tapping device **30** may be positioned a location of the communication link which provides an acceptable latency for the system's performance requirements. In some examples, the position may be based on a determination of a maximum or range of distances derived from the speed of the communication link and a maximum or range of acceptable backup latencies.

In some embodiments, the tapping device **30** may be positioned far enough from the communication device/system **10** such that a failure of a component of the communication device/system **10** is unlikely to prevent the backup message from reaching its destination.

In another example, when a backup message is sent via a number of interconnections and/or networking devices, the tapping device may provide a higher degree of confidence if it is positioned after the last interconnection or networking device between the communication device **10** and the backup device/system.

When a backup message is sent over the communication link **31**, the tapping device can tap a tap copy of the backup message as it is being transmitted along the communication link **31**.

At **240**, the communication device **10** can be configured to confirm a tap copy of the backup message from the tapping device. In some examples, this includes receiving a tap copy of the backup message. In some examples, the communication device **10** can be configured to verify the tap copy of the backup message. This can include verifying that the backup message has been sent over the communication link **31**, verifying that the backup message has been sent without errors, and/or verifying that the backup message correctly includes a copy of the message or data/instructions for recreating a message to be sent to the destination.

In some examples, verifying the tap copy may include generating a verifying an error correction code (ECC) and/or hash of the tap copy with an ECC and/or hash of the backup message.

In some examples, the tapping device **30** or other device may be configured to verify the tap copy, and to send a confirmation signal to the communication device **10**.

At **250**, upon confirmation of the tap copy of the backup message, the communication device **10** can be configured to send the message to the destination. In some scenarios, by confirming that the backup message has been sent or "launched" down a dedicated link or high reliability link/network, the communication device **10** can safely assume that the backup message will be arrive at the backup device. This assumption may, in some instances, be particularly reliable for an optical or other high speed link where signals travel close to the speed of light. In order for the message to be lost, the communication device **10** would have to fail after the backup message has been launched but before the message to the destination has been sent, and the communication link **31** would have to fail after the backup message has been launched but before the backup message, potentially travelling near the speed of light, arrives at the backup device **20**. In other words, in some embodiments, the transmission over the communication link **31** may be at a great enough speed that it may be assumed that once a message has been sent, there is a very small window of time during which a failure or nefarious activity can prevent message from reaching its destination.

In some embodiments, the backup device (or system) **20** may be configured to store the backup message for retrieval in the event of a failure of the communication device **10**. In

some embodiments, the backup device (or system) **20** may be a redundant communication device which can send the message (and/or recreate the message for sending) to the destination in the event the primary communication device **10** fails.

In some embodiments, the communication device **10** at **260** may be optionally configured to send a confirmation message to the source that the message has been delivered. This confirmation may occur after the confirmation of the tap message and/or concurrently with or after the sending of the message to the destination **250**.

In some examples, the communication device **10**, at **270**, can be configured to receive an acknowledgement message from the backup device **20** indicating the backup message was received, stored and/or processed. In some examples, the communication device **10** may be configured to use the acknowledgement message as a confirmation of the status/health of the backup system **20** as it does not wait for the acknowledgement before sending the message to the destination.

In some examples, the communication device **10** may be configured to send backup messages to a different backup system, if an acknowledgement message has not been received from a first backup system after a threshold time.

In some instances, the systems **200** and methods **201** described herein may allow for reliable data transmission with a high degree of certainty that a message will be sent without the inherent latencies of the system described in FIG. 1.

In some embodiments, the tapping device **30** may be positioned on the communication link **31** proximate to the communication device **10**. The closer the tapping device **30**, the lower the transmission latency for the backup message to travel from the communication device **10** to the tapping device **30**, and the lower the transmission latency for the tap copy or other signal to travel from the tapping device **30** to the communication device **10**.

In an example application, the systems **200**, devices, and methods **201** described herein may be used as part of a financial trading system. Trade request data may be received from a source or generated by a communication device **20** for transmission to a trade execution device (destination) at a stock exchange. Due to potentially large financial consequences if a trade request fails to be sent or is sent too late (allowing prices or liquidity to change), the system **200** may, in some examples, provide a suitable system for timely and reliable transmission of trade requests.

In some instances, embodiments of the systems, devices, and methods described herein may be used in other environments requiring high reliability and/or time critical communications. Examples include but are not limited to military, government, bank, telecom, etc. In some examples, embodiments of the systems, devices, and methods described herein may be useful for service providers to provide various service level requirements.

FIG. 3 shows aspects of another example system **200**, and flowchart **201** illustrating another example communication process. In FIG. 3, the communication device **10** can be configured to send a backup message to both a first backup device **20** and a second backup device **20a** before sending a message to the destination.

In some embodiments, the first and second backup devices **20**, **20a** are at different locations, and/or are located in different directions from the communication system/device **10**.

In some embodiments, the communication link for sending **230** the backup message to the first backup system **20** is

different from the communication link for sending **230a** the backup message to the second backup system **20a**. For example, the respective backup messages can be sent along different physical communication connections, sent from/via different network devices and/or in different directions. In some instances, the use of such different physical communication connections may reduce the change that both backup messages are lost.

While, FIG. 3 shows an example system **200** which utilizes two backup systems **20**, **20a**, in other embodiments, three, four or any number of backup systems may be used, each with their own respective taps and communication links. In some embodiments, this may create additional redundancy and/or reliability.

In some examples, the communication device **10** can be configured to send the message to the destination upon confirmation of a tap copy from at least one of the tapping devices **30**, **30a**. In some such examples, the system **200** and methods **201** may provide a further layer of redundancy without any additional backup delay.

In some examples, for a potentially higher degree of reliability, the communication device **10** can be configured to only send the message to the destination upon confirmation of a tap copy from both of the tapping devices **30**, **30a**. In embodiments having three or more backup systems, the communication device **10** can be configured to only send the message to the destination upon confirmation of a tap copy from two or more of the backup systems.

As described herein or otherwise, in some embodiments, the communication system **10** is configured to send backup messages to a subset of all available backup systems. The communication system **10** may be configured to send backup messages to additional backup system(s) when acknowledgement messages are not received within a defined threshold time.

In some embodiments as described with respect to FIG. 2 or 3, the communication system **10** may concurrently act as backup system for another system/device such as the backup devices **20**, **20a**.

The backup system(s) **20**, **20a** are configured to send an acknowledgment message to the communication system **10** upon receipt of a backup message. In some examples, these acknowledgement messages can be used by the communication system **10** as a health indicator or status check on the corresponding communication link **31** and/or backup system **20**.

In some embodiments, the backup system(s) are configured to send heartbeat messages to the communication system **10**. The heartbeat message can be sent periodically (e.g. every 10 ms) to the communication system **10** to act as a health indicator or status check on the corresponding communication link **31** and/or backup system **20**.

In some embodiments, the heartbeat messages may only be sent when an acknowledgement message has not been sent recently or within the last heartbeat period. In other embodiments, the heartbeat messages are sent periodically irrespective of any acknowledgement messages. In some examples, the use of heartbeat messages can provide the communication system a relatively current indication of the health of the backup link(s) and/or system even if a backup message has not been sent to the backup system recently.

In some embodiments, the heartbeat messages can include a sequence number or some identifier with which the communication system **10** can determine whether a particular heartbeat message was not successfully received.

Alternatively or additionally, in some embodiments, the communication system **10** can be configured to send heart-

beat messages to the backup system 20. This can cause the communication system 10 to receive tap copies of the heartbeat messages from the tap device 30, and acknowledgement heartbeat messages from the backup system 20. In some such embodiments, the heartbeat messages can provide an indication of the health/performance of the tap device 30, communication links and backup system 20.

In some embodiments, when the communication system 10 does not receive an acknowledgement or heartbeat message (originating from the backup system or as an acknowledgement of an original heartbeat message received from the communication system) within a defined time threshold (e.g. within 500 microseconds of sending a backup or original heartbeat message, or within 350 microseconds of an expected heartbeat message), a secondary or failure mode may be triggered. For example, in a secondary mode, the communication system 10 may be configured to stop sending backup messages to a primary backup system from which acknowledgement or heartbeat messages have not been received within the defined threshold, and may send all subsequent backup messages to a different backup system.

In other embodiments, when a secondary or failure mode is triggered, the communication system 10 can be configured to utilize a different backup mechanism. In some examples, the communication system can use a traditional backup mechanism which may have a longer latency and/or slower throughput than the tap mechanism described herein. For example, the communication system operating in a secondary mode may store a backup message locally or otherwise within the communication system 10.

In some embodiments, when a secondary or failure mode is triggered, the communication system/device 10 may continue to send messages to the destination despite the loss or unreliability of a backup system. In some examples, the communication system/device 10 may generate an alert or electronic message providing an indication that the system 200 is operating in a mode that cannot guarantee a recovery should a failure occur.

In some examples, the communication system(s)/device(s) 10 can use heartbeat messages and any associated tap copies and acknowledgement heartbeat messages to monitor latencies between the transmission of a backup copy and the receipt of a tap copy or an acknowledgement message. In some embodiments, the monitoring of latencies can include using timestamps in heartbeat and/or acknowledgement messages, or by monitoring clock times of transmission or receipt of messages. In some examples, then the communication system 10 detects a monitored latency which indicates a change from a historical or expected latency, the communication system 10 can be configured to generate an alert. Such a change in latency may, in some instances, be indicative of a hardware or software problem, a change in topology, a backlog at the backup system, etc. The alert may allow for more comprehensive testing or investigation to be performed before a catastrophic problem occurs.

While the disclosure has been provided and illustrated in connection with specific, presently-preferred embodiments, many variations and modifications may be made without departing from the spirit and scope of the invention(s) disclosed herein. The disclosure and invention(s) are therefore not to be limited to the exact components or details of methodology or construction set forth above. Except to the extent necessary or inherent in the processes themselves, no particular order to steps or stages of methods or processes described in this disclosure, including the Figures, is intended or implied. In many cases the order of process steps may be varied without changing the purpose, effect, or

import of the methods described. The scope of the claims is to be defined solely by the appended claims, giving due consideration to the doctrine of equivalents and related doctrines.

What is claimed is:

1. A communication system, the system comprising:
 - a first communication device configured to communicate with a backup device and a destination;
 - a first tapping device for monitoring messages sent over a first communication link between the first communication device and the backup device, the first communication link being a dedicated or high reliability link/network adapted such that the first communication device can safely assume that the backup will arrive at the backup device;
 - the first communication device including at least one processor configured to:
 - before sending a first message destined for the destination, send a backup message corresponding to the first message over the first communication link for backup at the backup device;
 - upon confirmation of a tap copy of the backup message from the first tapping device, send the first message to the destination; and
 - send a confirmation message to a source device to indicate that the first message has been delivered, the confirmation message sending after the confirmation of the tap copy of the backup message.
2. The communication system of claim 1, wherein the at least one processor is configured to: verify the tap copy before sending the first message to the destination.
3. The communication system of claim 1, wherein the backup message includes a copy of the first message.
4. The communication system of claim 1, wherein the backup message includes information that can be used to recreate the first message or create a substitute message.
5. The communication system of claim 1, wherein the communication link between the first communication device and the backup device is an undivided physical communication link.
6. The communication system of claim 1, wherein the first tapping device is positioned at a position on the communication link that is closer to the first communication device than the backup device.
7. The communication system of claim 1, wherein the at least one processor is configured to: verify a status of the backup device based on an acknowledgement message received from the backup device, the acknowledgement message indicating that the backup message was received.
8. The communication system of claim 1, comprising: a second tapping device for monitoring messages sent over a second communication link between the first communication device and a second backup device;
 - wherein the at least one processor is configured to:
 - before sending the first message destined for the destination, send the backup message over the second communication link; and
 - upon confirmation of the tap copy from at least one of the first tapping device or the second tapping device, send the first message to the destination.
9. The communication system of claim 1, wherein the at least one processor is configured to receive heartbeat messages from the backup device.
10. The communication system of claim 1, wherein the at least one processor is configured to send heartbeat messages over the first communication link to the backup device, and

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to receive corresponding tap messages from the first tapping device and acknowledgement heartbeat messages from the backup device.

11. The communication system of claim 1, wherein the at least one processor is configured to trigger a secondary backup mode when an acknowledgement message or heartbeat message is not received within a defined time threshold.

12. The communication system of claim 11, wherein in a secondary backup mode, the at least one processor is configured to send the backup message to second backup device.

13. A communication device comprising:
at least one processor configured to:

before sending a first message destined for a destination, send a backup message corresponding to the first message over a communication link for backup at the backup device, the communication link being a dedicated or high reliability link/network adapted such that the communication device can safely assume that the backup will arrive at the backup device;

upon confirmation of a tap copy of the backup message from a tapping device on the communication link, send the first message to the destination; and

sending a confirmation message to a source device to indicate that the first message has been delivered, the confirmation message sending after the confirmation of the tap copy of the backup message.

14. The communication device of claim 13, wherein the at least one processor is configured to: verify the tap copy before sending the first message to the destination.

15. The communication device of claim 13, wherein the backup message includes a copy of the first message.

16. The communication device of claim 13, wherein the backup message includes information that can be used to recreate the first message or create a substitute message.

17. The communication device of claim 13, wherein the communication link between the first communication device and the backup device is an undivided physical communication link.

18. The communication device of claim 13, wherein the tapping device is positioned at a position on the communication link that is closer to the first communication device than the backup device.

19. The communication device of claim 13, wherein the at least one processor is configured to: verify a status of the backup device based on an acknowledgement message received from the backup device, the acknowledgement message indicating that the backup message was received.

20. The communication device of claim 13 wherein the at least one processor is configured to:

before sending the first message destined for the destination, send the backup message over a second communication link for backup at a second backup device; and upon confirmation of the tap copy from at least one of the tapping device on the communication link, or a second tapping device on the second communication link, send the first message to the destination.

21. The communication device of claim 13, wherein the at least one processor is configured to receive heartbeat messages from the backup device.

22. The communication device of claim 13, wherein the at least one processor is configured to send heartbeat messages over the communication link to the backup device, and to receive corresponding tap messages from the tapping device and acknowledgement heartbeat messages from the backup device.

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23. The communication device of claim 13, wherein the at least one processor is configured to trigger a secondary backup mode when an acknowledgement message or heartbeat message is not received within a defined time threshold.

24. The communication device of claim 23, wherein in a secondary backup mode, the at least one processor is configured to send the backup message to the second backup device.

25. A communication method comprising:

before sending, from a communication device, a first message destined for a destination, sending a backup message corresponding to the first message from the communication device to a backup device over a communication link being a dedicated or high reliability link/network adapted such that the communication device can safely assume that the backup will arrive at the backup device;

upon confirmation of a tap copy of the backup message from a passive tapping device on the communication link, sending the first message to the destination; and sending a confirmation message to a source device to indicate that the first message has been delivered, the confirmation message sending after the confirmation of the tap copy of the backup message.

26. The method of claim 25, comprising verifying the tap copy before sending the first message to the destination.

27. The method of claim 25, wherein the backup message includes a copy of the first message.

28. The method of claim 25, wherein the backup message includes information that can be used to recreate the first message or create a substitute message.

29. The method of claim 25, wherein the communication link between the first communication device and the backup device is an undivided physical communication link.

30. The method of claim 25, wherein the first passive tapping device is positioned at a position on the communication link that is closer to the first communication device than the backup device.

31. The method of claim 25, comprising verifying a status of the backup device based on an acknowledgement message received from the backup device, the acknowledgement message indicating that the backup message was received.

32. The method of claim 25 comprising: before sending the first message destined for the destination, sending the backup message over a second communication link; and upon confirmation of a tap copy from at least one of the tapping device on the communication link or a second tapping device on the second communication link, send the first message to the destination.

33. The method of claim 25, comprising receiving heartbeat messages from the backup device.

34. The method of claim 25, comprising: sending heartbeat messages over the communication link to the backup device; and receiving corresponding tap messages from the first tapping device and acknowledgement heartbeat messages from the backup device.

35. The method of claim 25, comprising: triggering a secondary backup mode when an acknowledgement message or heartbeat message is not received within a defined time threshold.

36. The method of claim 35, wherein triggering the secondary backup mode, comprises sending the backup message to the second backup device.

37. The system of claim 1, wherein the first tapping device allows signals sent from the first communication device to the backup device to pass uninterrupted while monitoring

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the messages sent over the first communication link between
the first communication device and the backup device.

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