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(54) **PRODUCTION OF CRYPTOGRAPHIC KEYS FOR AN EMBEDDED PROCESSING DEVICE**

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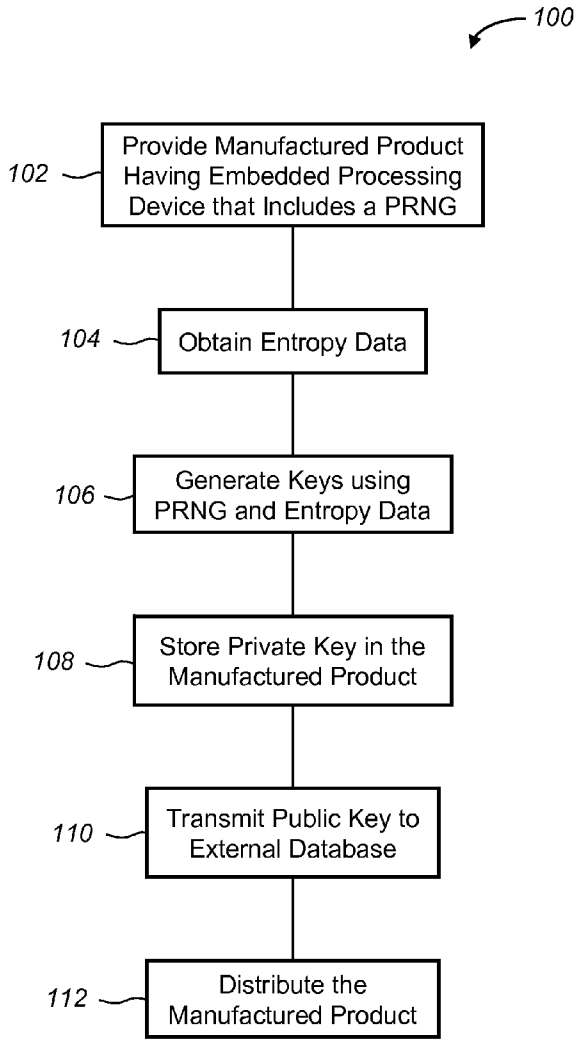
(57) **ABSTRACT**

A system and method for producing cryptographic keys for use by an embedded processing device within a manufactured product. A pseudo random number generator is seeded with entropy data gathered by the embedded device, and the result is used to generate a public-private key pair. The process can be carried out during manufacturing so that the public key of each manufactured product can be stored in a database along with a unique identifier for the embedded device associated with the key. In one particular example, a vehicle having an installed telematics unit uses the key generating process to self-generate keys using entropy data available to the vehicle.



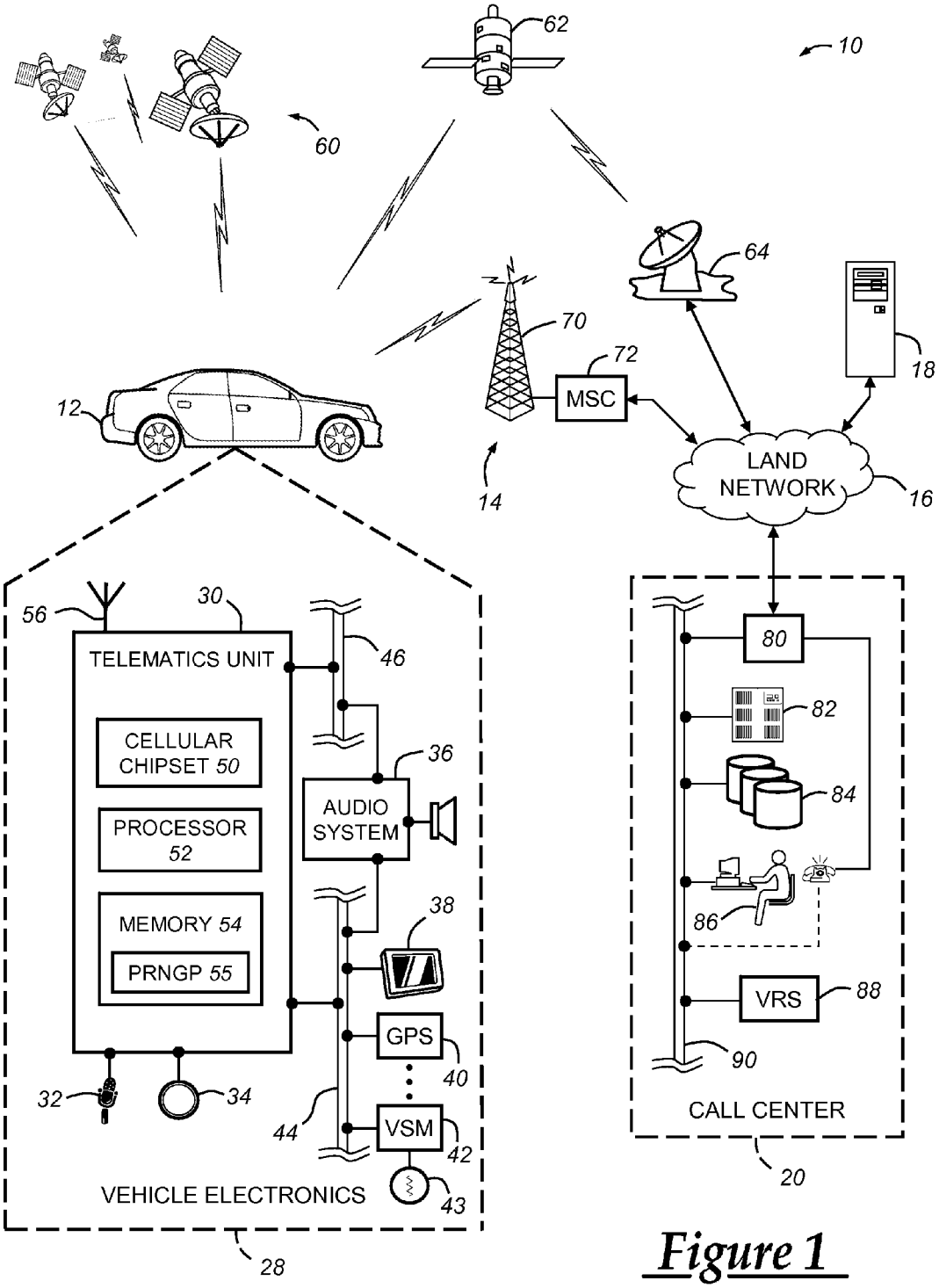

62
10
60
64
70
72
MSC
18
12
LAND NETWORK
16
14
56
30
TELEMATICS UNIT
46
CELLULAR CHIPSET 50
36
AUDIO SYSTEM
PROCESSOR 52
MEMORY 54
PRNGP 55
38
GPS
40
32
34
44
VSM
42
43
VEHICLE ELECTRONICS
28
80
82
84
86
VRS
88
90
CALL CENTER
20

Figure 1

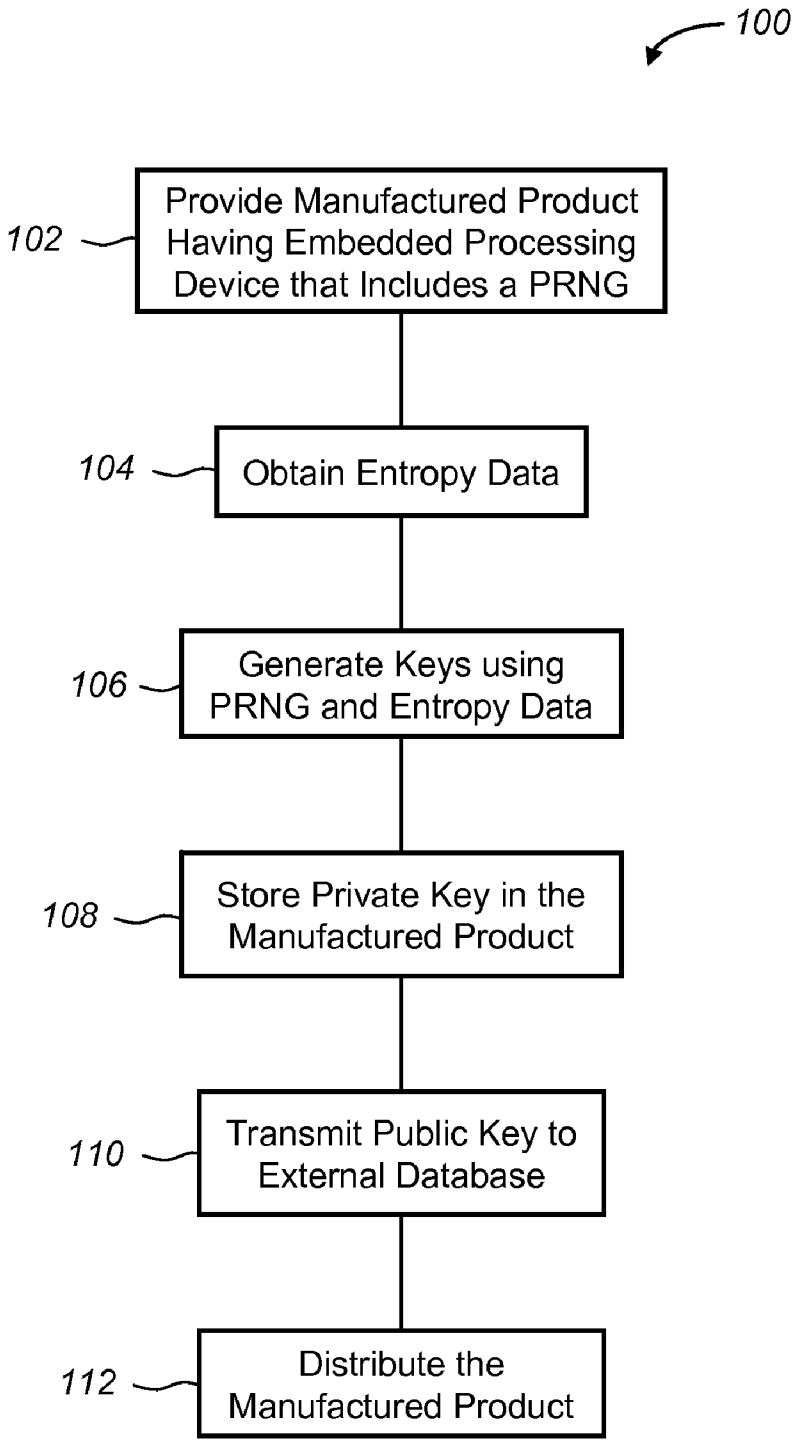

100
102
Provide Manufactured Product Having Embedded Processing Device that Includes a PRNG
104
Obtain Entropy Data
106
Generate Keys using PRNG and Entropy Data
108
Store Private Key in the Manufactured Product
110
Transmit Public Key to External Database
112
Distribute the Manufactured Product

Figure 2

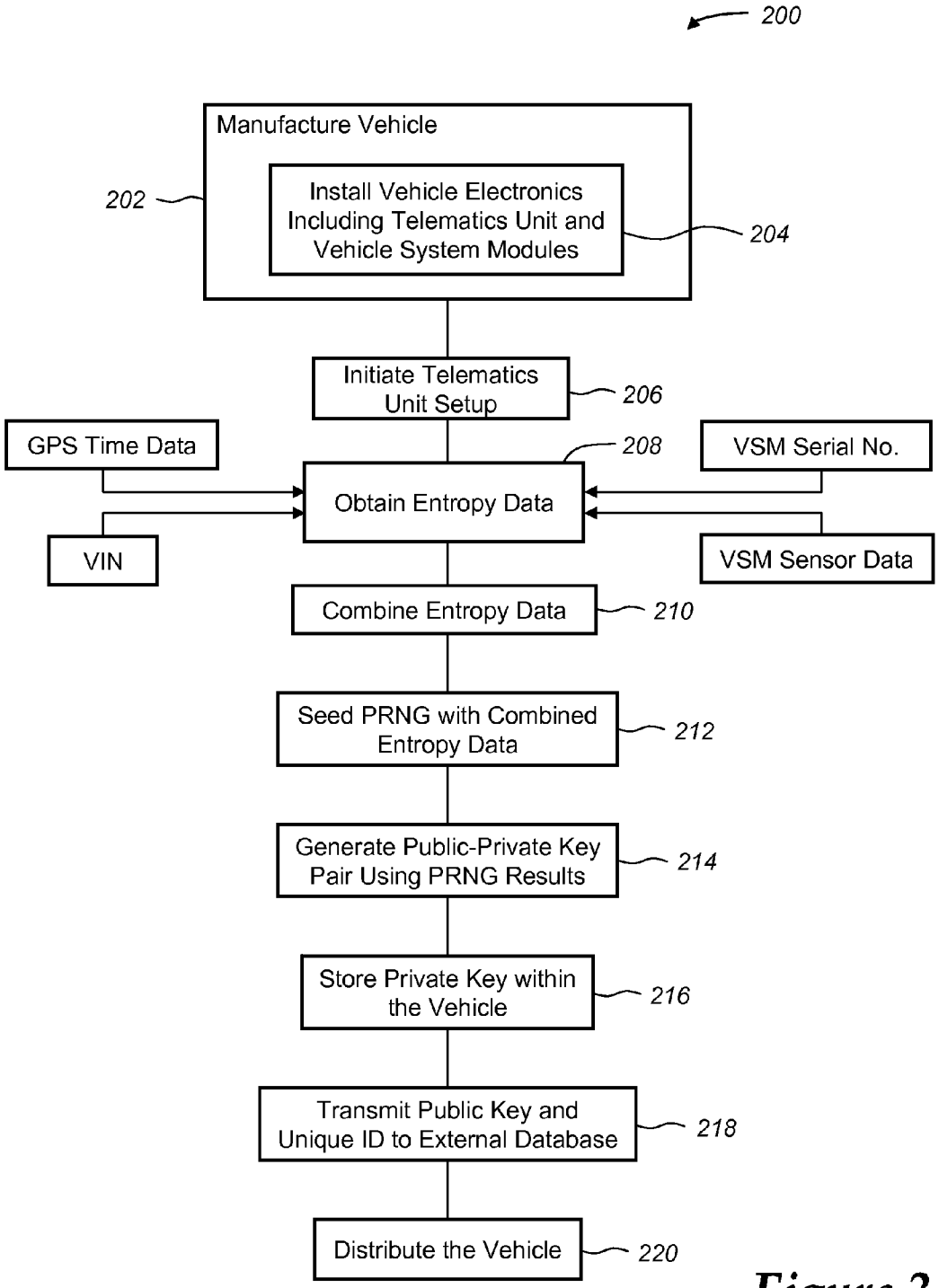

200
Manufacture Vehicle
202
Install Vehicle Electronics Including Telematics Unit and Vehicle System Modules
204
Initiate Telematics Unit Setup
206
GPS Time Data
208
VSM Serial No.
Obtain Entropy Data
VIN
VSM Sensor Data
Combine Entropy Data
210
Seed PRNG with Combined Entropy Data
212
Generate Public-Private Key Pair Using PRNG Results
214
Store Private Key within the Vehicle
216
Transmit Public Key and Unique ID to External Database
218
Distribute the Vehicle
220

*Figure 3*

# PRODUCTION OF CRYPTOGRAPHIC KEYS FOR AN EMBEDDED PROCESSING DEVICE

## TECHNICAL FIELD

**[0001]** The present invention relates generally to techniques for generating cryptographic keys used in secure data communications and, in particular, to such techniques used for manufactured products having embedded processing devices.

## BACKGROUND OF THE INVENTION

**[0002]** As computer electronics continue to reduce in cost and size, the applications for embedded processing devices are continuing to increase, and there now exists many types of manufactured products that contain some type of embedded processing device, whether microprocessor based or otherwise. Some embedded devices are designed to undergo data communication with one or more external, possibly remote devices. In some cases, it is desirable to establish authenticated, secure data communications in which the exchanged data is encrypted. Although various approaches can be used, cryptographic keys are perhaps most commonly used for this purpose. In public key cryptography, a public-private key pair is created with the public key then being available for use by anyone desiring encrypted communication with the holder of the private key. Digital certificates issued by a trusted third party (certificate authority) can also be used to authenticate the public key to a particular entity.

**[0003]** The generation of strong cryptographic keys typically involves the use of random data that cannot be later discerned or uncovered. For this purpose, general purpose computers such as desktop, laptop, and notebook personal computers can include entropy hardware or software engines that generate entropy data as a quantifiable form of random or near-random data for use in generating the cryptographic keys. This entropy data can be obtained in a variety of different ways, such as through software by, for example, timing the intervals between a user's keystrokes, detecting the user's movement of a mouse or other serial input device, or timing the arrival of packets at the computer from an attached network. Such data can also be obtained through entropy hardware engines in the computer that, for example, generate random data based on measured physical effects such as thermal noise (e.g., temperature variations about some given threshold). The cryptographic keys can then be generated using this entropy data since it is both transient and at least nearly truly random.

**[0004]** As applied to embedded processing devices, the generation of the cryptographic keys can be problematic because they typically do not have entropy hardware or software engines of the type found in personal computers. Instead pseudo random number generators (PRNG) are typically used. These PRNGs are generally implemented in software and require a seed value that is used to generate a pseudo-random number. This generated number is then used to produce the cryptographic keys. The generation of strong keys using PRNGs generally necessitates the use of a seed value that cannot later be discovered. For an embedded processing device having restricted computing capabilities, obtaining such a seed value can be problematic.

## SUMMARY OF THE INVENTION

**[0005]** According to one aspect of the invention, there is provided a method of producing cryptographic keys for use in communicating with a manufactured product having an embedded processing device, comprising the steps of:

**[0006]** (a) providing a manufactured product having an embedded processing device that includes a pseudo random number generator (PRNG);

**[0007]** (b) obtaining entropy data;

**[0008]** (c) generating public and private cryptographic keys using the pseudo random number generator and the entropy data;

**[0009]** (d) storing the private key within the manufactured product;

**[0010]** (e) transmitting the public key from the manufactured product for storage in a database external to the manufactured product; and

**[0011]** (f) transferring possession of the manufactured product to another entity.

**[0012]** The method can be used in conjunction with a variety of manufactured products. In one embodiment, the manufactured product is a vehicle and the embedded device is a telematics unit installed in the vehicle.

**[0013]** In accordance with another aspect of the invention, there is provided a vehicle electronics system for self-generating cryptographic keys used for secure wireless communication with the vehicle. The vehicle electronics include a telematics unit, a communications bus connected to the telematics unit, and a plurality of vehicle system modules. The telematics unit has a processor, memory, and a cellular chipset, with the processor being operable to execute instructions stored in the memory and control wireless communication of cellular voice and data calls via the cellular chipset. At least some of the vehicle system modules are connected to the communications bus such that the telematics unit can receive data from the connected vehicle system modules. The telematics unit includes a pseudo random number generator and is operable under control of the processor to obtain entropy data from at least one independent data source external to the telematics unit and to generate cryptographic keys using the pseudo random number generator and the entropy data.

**[0014]** As used herein, "entropy data" need not be truly random data, but can be any data not readily discernible either externally of the manufactured product or after being collected and used in generating the keys. In the former case, this protects against key compromise by those not in possession of the manufactured article. In the latter, this protects against key compromise by anyone not having access to the entropy data at the time of key production. This is especially useful for manufactured products designed to generate the keys at the time of manufacturing, since cryptographic key production can be done under circumstances in which access to the device, and thus the entropy data, is prevented or at least controlled. Another benefit of producing the keys at the time of manufacturing is that the public key can be stored in a database in conjunction with one or more identifiers for the device, again under controlled circumstances.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0015]** One or more preferred exemplary embodiments of the invention will hereinafter be described in conjunction with the appended drawings, wherein like designations denote like elements, and wherein:

**[0016]** FIG. **1** is a block diagram depicting an exemplary embodiment of a communications system that is capable of utilizing the method disclosed herein;

**[0017]** FIG. **2** is a flow chart of an exemplary embodiment of a method for producing cryptographic keys for an embedded processing device; and

**[0018]** FIG. **3** is a flow chart of an exemplary embodiment of a method for producing cryptographic keys for use in communicating with a vehicle having an installed telematics unit.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

**[0019]** The system and method described below enables the automatic generation of strong cryptographic keys by an embedded processing device at the time of manufacturing, before the product is released for distribution to end users. This is accomplished at least in part by supplying the embedded device with entropy data that it uses to seed a pseudo random number generator (PRNG) that is used to generate the keys. This entropy data can be obtained by the embedded device from any of a number of sources, including those both internal and external to the manufactured product. In the illustrated exemplary embodiment described below, the embedded device comprises a telematics unit installed in an automobile. However, it will be appreciated by those skilled in the art that the invention can be used in conjunction with any of a number of different embedded processing devices and manufactured products.

### Communications System

**[0020]** With reference to FIG. **1**, there is shown a vehicle **12** with its onboard electronics **28** that includes a telematics unit **30** constructed to carry out the cryptographic key generating methods of FIGS. **2** and **3**. Also shown is an exemplary operating environment in the form of a mobile vehicle communications system **10** within which the telematics unit **30** is used in normal operation. Communications system **10** generally includes the vehicle **12**, one or more wireless carrier systems **14**, a land communications network **16**, a computer **18**, and a call center **20**. It should be understood that the disclosed method can be used with any number of different systems and manufactured products and is not specifically limited to the telematics unit or operating environment shown here. Also, the architecture, construction, setup, and operation of the system **10** and its individual components are generally known in the art. Thus, the following paragraphs simply provide a brief overview of one such exemplary system **10**; however, other systems not shown here could employ the disclosed method as well.

**[0021]** Vehicle **12** is depicted in the illustrated embodiment as a passenger car, but it should be appreciated that any other vehicle including motorcycles, trucks, sports utility vehicles (SUVs), recreational vehicles (RVs), marine vessels, aircraft, etc., can also be used. Some of the vehicle electronics **28** is shown generally in FIG. **1** and includes a telematics unit **30**, a microphone **32**, one or more pushbuttons or other control inputs **34**, an audio system **36**, a visual display **38**, and a GPS module **40** as well as a number of vehicle system modules (VSMs) **42**. Some of these devices can be connected directly to the telematics unit such as, for example, the microphone **32** and pushbutton(s) **34**, whereas others are indirectly connected using one or more network connections, such as a communications bus **44** or an entertainment bus **46**. Examples of suitable network connections include a controller area network (CAN), a media oriented system transfer (MOST), a local interconnection network (LIN), a local area network (LAN), and other appropriate connections such as Ethernet or others that conform with known ISO, SAE and IEEE standards and specifications, to name but a few.

**[0022]** Telematics unit **30** is an OEM-installed device that enables wireless voice and/or data communication over wireless carrier system **14** and via wireless networking so that the vehicle can communicate with call center **20**, other telematics-enabled vehicles, or some other entity or device. The telematics unit preferably uses radio transmissions to establish a communications channel (a voice channel and/or a data channel) with wireless carrier system **14** so that voice and/or data transmissions can be sent and received over the channel. By providing both voice and data communication, telematics unit **30** enables the vehicle to offer a number of different services including those related to navigation, telephony, emergency assistance, diagnostics, infotainment, etc. Data can be sent either via a data connection, such as via packet data transmission over a data channel, or via a voice channel using techniques known in the art. For combined services that involve both voice communication (e.g., with a live advisor or voice response unit at the call center **20**) and data communication (e.g., to provide GPS location data or vehicle diagnostic data to the call center **20**), the system can utilize a single call over a voice channel and switch as needed between voice and data transmission over the voice channel, and this can be done using techniques known to those skilled in the art.

**[0023]** According to one embodiment, telematics unit **30** utilizes cellular communication according to either GSM or CDMA standards and thus includes a standard cellular chipset **50** for voice communications like hands-free calling, a wireless modem for data transmission, an electronic processor **52**, one or more digital memory devices **54**, and a dual antenna **56**. It should be appreciated that the modem can either be implemented through software that is stored in the telematics unit and is executed by processor **52**, or it can be a separate hardware component located internal or external to telematics unit **30**. The modem can operate using any number of different standards or protocols such as EVDO, CDMA, GPRS, and EDGE. Wireless networking between the vehicle and other networked devices can also be carried out using telematics unit **30**. For this purpose, telematics unit **30** can be configured to communicate wirelessly according to one or more wireless protocols, such as any of the IEEE 802.11 protocols, WiMAX, or Bluetooth. When used for packet-switched data communication such as TCP/IP, the telematics unit can be configured with a static IP address or can set up to automatically receive an assigned IP address from another device on the network such as a router or from a network address server.

**[0024]** Processor **52** can be any type of device capable of processing electronic instructions including microprocessors, microcontrollers, host processors, controllers, vehicle communication processors, and application specific integrated circuits (ASICs). It can be a dedicated processor used only for telematics unit **30** or can be shared with other vehicle systems. Processor **52** executes various types of digitally-stored instructions, such as software or firmware programs stored in memory **54**, which enable the telematics unit to provide a wide variety of services. For instance, processor **52** can execute programs or process data to carry out at least a part of the method discussed herein.

**[0025]** Telematics unit **30** can be used to provide a diverse range of vehicle services that involve wireless communica-

tion to and/or from the vehicle. Such services include: turn-by-turn directions and other navigation-related services that are provided in conjunction with the GPS-based vehicle navigation module **40**; airbag deployment notification and other emergency or roadside assistance-related services that are provided in connection with one or more collision sensor interface modules such as a body control module (not shown); diagnostic reporting using one or more diagnostic modules; and infotainment-related services where music, webpages, movies, television programs, videogames and/or other information is downloaded by an infotainment module (not shown) and is stored for current or later playback. The above-listed services are by no means an exhaustive list of all of the capabilities of telematics unit **30**, but are simply an enumeration of some of the services that the telematics unit is capable of offering. Furthermore, it should be understood that at least some of the aforementioned modules could be implemented in the form of software instructions saved internal or external to telematics unit **30**, they could be hardware components located internal or external to telematics unit **30**, or they could be integrated and/or shared with each other or with other systems located throughout the vehicle, to cite but a few possibilities. In the event that the modules are implemented as VSMs **42** located external to telematics unit **30**, they could utilize vehicle bus **44** to exchange data and commands with the telematics unit.

**[0026]** GPS module **40** receives radio signals from a constellation **60** of GPS satellites. From these signals, the module **40** can determine vehicle position that is used for providing navigation and other position-related services to the vehicle driver. Navigation information can be presented on the display **38** (or other display within the vehicle) or can be presented verbally such as is done when supplying turn-by-turn navigation. The navigation services can be provided using a dedicated in-vehicle navigation module (which can be part of GPS module **40**), or some or all navigation services can be done via telematics unit **30**, wherein the position information is sent to a remote location for purposes of providing the vehicle with navigation maps, map annotations (points of interest, restaurants, etc.), route calculations, and the like. The position information can be supplied to call center **20** or other remote computer system, such as computer **18**, for other purposes, such as fleet management. Also, new or updated map data can be downloaded to the GPS module **40** from the call center **20** via the telematics unit **30**.

**[0027]** Apart from the audio system **36** and GPS module **40**, the vehicle **12** can include other vehicle system modules (VSMs) **42** in the form of electronic hardware components that are located throughout the vehicle and typically receive input from one or more sensors and use the sensed input to perform diagnostic, monitoring, control, reporting and/or other functions. Each of the VSMs **42** is preferably connected by communications bus **44** to the other VSMs, as well as to the telematics unit **30**, and can be programmed to run vehicle system and subsystem diagnostic tests. As examples, one VSM **42** can be an engine control module (ECM) that controls various aspects of engine operation such as fuel ignition and ignition timing, another VSM **42** can be a powertrain control module that regulates operation of one or more components of the vehicle powertrain, and another VSM **42** can be a body control module that governs various electrical components located throughout the vehicle, like the vehicle's power door locks and headlights. According to one embodiment, the engine control module is equipped with on-board diagnostic (OBD) features that provide myriad real-time data, such as that received from various sensors including vehicle emissions sensors, and provide a standardized series of diagnostic trouble codes (DTCs) that allow a technician to rapidly identify and remedy malfunctions within the vehicle. As is appreciated by those skilled in the art, the above-mentioned VSMs are only examples of some of the modules that may be used in vehicle **12**, as numerous others are also possible.

**[0028]** Vehicle electronics **28** also includes a number of vehicle user interfaces that provide vehicle occupants with a means of providing and/or receiving information, including microphone **32**, pushbuttons(s) **34**, audio system **36**, and visual display **38**. As used herein, the term 'vehicle user interface' broadly includes any suitable form of electronic device, including both hardware and software components, which is located on the vehicle and enables a vehicle user to communicate with or through a component of the vehicle. Microphone **32** provides audio input to the telematics unit to enable the driver or other occupant to provide voice commands and carry out hands-free calling via the wireless carrier system **14**. For this purpose, it can be connected to an on-board automated voice processing unit utilizing human-machine interface (HMI) technology known in the art. The pushbutton(s) **34** allow manual user input into the telematics unit **30** to initiate wireless telephone calls and provide other data, response, or control input. Separate pushbuttons can be used for initiating emergency calls versus regular service assistance calls to the call center **20**. Audio system **36** provides audio output to a vehicle occupant and can be a dedicated, stand-alone system or part of the primary vehicle audio system. According to the particular embodiment shown here, audio system **36** is operatively coupled to both vehicle bus **44** and entertainment bus **46** and can provide AM, FM and satellite radio, CD, DVD and other multimedia functionality. This functionality can be provided in conjunction with or independent of the infotainment module described above. Visual display **38** is preferably a graphics display, such as a touch screen on the instrument panel or a heads-up display reflected off of the windshield, and can be used to provide a multitude of input and output functions. Various other vehicle user interfaces can also be utilized, as the interfaces of FIG. **1** are only an example of one particular implementation.

**[0029]** Wireless carrier system **14** is preferably a cellular telephone system that includes a plurality of cell towers **70** (only one shown), one or more mobile switching centers (MSCs) **72**, as well as any other networking components required to connect wireless carrier system **14** with land network **16**. Each cell tower **70** includes sending and receiving antennas and a base station, with the base stations from different cell towers being connected to the MSC **72** either directly or via intermediary equipment such as a base station controller. Cellular system **14** can implement any suitable communications technology, including for example, analog technologies such as AMPS, or the newer digital technologies such as CDMA (e.g., CDMA2000) or GSM/GPRS. As will be appreciated by those skilled in the art, various cell tower/base station/MSC arrangements are possible and could be used with wireless system **14**. For instance, the base station and cell tower could be co-located at the same site or they could be remotely located from one another, each base station could be responsible for a single cell tower or a single base station could service various cell towers, and various base stations could be coupled to a single MSC, to name but a few of the possible arrangements.

**[0030]** Apart from using wireless carrier system **14**, a different wireless carrier system in the form of satellite communication can be used to provide uni-directional or bi-directional communication with the vehicle. This can be done using one or more communication satellites **62** and an uplink transmitting station **64**. Uni-directional communication can be, for example, satellite radio services, wherein programming content (news, music, etc.) is received by transmitting station **64**, packaged for upload, and then sent to the satellite **62**, which broadcasts the programming to subscribers. Bi-directional communication can be, for example, satellite telephony services using satellite **62** to relay telephone communications between the vehicle **12** and station **64**. If used, this satellite telephony can be utilized either in addition to or in lieu of wireless carrier system **14**.

**[0031]** Land network **16** may be a conventional land-based telecommunications network that is connected to one or more landline telephones and connects wireless carrier system **14** to call center **20**. For example, land network **16** may include a public switched telephone network (PSTN) such as that used to provide hardwired telephony, packet-switched data communications, and the Internet infrastructure. One or more segments of land network **16** could be implemented through the use of a standard wired network, a fiber or other optical network, a cable network, power lines, other wireless networks such as wireless local area networks (WLANs), or networks providing broadband wireless access (BWA), or any combination thereof. Furthermore, call center **20** need not be connected via land network **16**, but could include wireless telephony equipment so that it can communicate directly with a wireless network, such as wireless carrier system **14**.

**[0032]** Computer **18** can be one of a number of computers accessible via a private or public network such as the Internet. Each such computer **18** can be used for one or more purposes, such as a web server accessible by the vehicle via telematics unit **30** and wireless carrier **14**. Other such accessible computers **18** can be, for example: a service center computer where diagnostic information and other vehicle data can be uploaded from the vehicle via the telematics unit **30**; a client computer used by the vehicle owner or other subscriber for such purposes as accessing or receiving vehicle data or to setting up or configuring subscriber preferences or controlling vehicle functions; or a third party repository to or from which vehicle data or other information is provided, whether by communicating with the vehicle **12** or call center **20**, or both. A computer **18** can also be used for providing Internet connectivity such as DNS services or as a network address server that uses DHCP or other suitable protocol to assign an IP address to the vehicle **12**.

**[0033]** Call center **20** is designed to provide the vehicle electronics **28** with a number of different system back-end functions and, according to the exemplary embodiment shown here, generally includes one or more switches **80**, servers **82**, databases **84**, live advisors **86**, as well as an automated voice response system (VRS) **88**, all of which are known in the art. These various call center components are preferably coupled to one another via a wired or wireless local area network **90**. Switch **80**, which can be a private branch exchange (PBX) switch, routes incoming signals so that voice transmissions are usually sent to either the live adviser **86** by regular phone or to the automated voice response system **88** using VoIP. The live advisor phone can also use VoIP as indicated by the broken line in FIG. **1**. VoIP and other data communication through the switch **80** is implemented via a modem (not shown) connected between the switch **80** and network **90**. Data transmissions are passed via the modem to server **82** and/or database **84**. Database **84** can store account information such as subscriber authentication information, vehicle identifiers, profile records, behavioral patterns, and other pertinent subscriber information. Data transmissions may also be conducted by wireless systems, such as 802.11x, GPRS, and the like. Although the illustrated embodiment has been described as it would be used in conjunction with a manned call center **20** using live advisor **86**, it will be appreciated that the call center can instead utilize VRS **88** as an automated advisor or, a combination of VRS **88** and the live advisor **86** can be used.

Cryptographic Key Production Methods

**[0034]** Turning now to FIG. **2**, there is shown a first embodiment **100** of a method of producing cryptographic keys. This embodiment is generic to the particular type of manufactured product and embedded device; thus, it is applicable to any manufacture having an electronics-based processing device incorporated therein. The process begins at step **102** wherein a manufactured product is provided having an embedded processing device that includes a pseudo random number generator (PRNG). Typically, this step will occur as a part of, or at the tail end of the manufacturing process such that this step, if not all of the steps of method **100**, will be carried out while the product is still under the possession of the manufacturer. As one particular example, where the processing device is programmed to self-generate its keys, then steps **102-110** can be carried out after the manufactured product is fully completed, but prior to actual distribution. As will be appreciated, by performing this process for each manufactured product, a database of public keys and product identifiers can be built up as a part of the overall manufacturing process. Optionally, these steps can be carried out while the product is in the possession of an entity other than the manufacturer, such as by a dealer who has possession of the product prior to its delivery to an end user.

**[0035]** At step **104**, the processing device obtains entropy data. This entropy data can come from one or more sources that provide data having either or both of the following attributes: (1) it is transient and not later discernible, or (2) it is internal to the manufactured product and not readily discernible without possession and analysis of the product. Although other types of entropy data can be used, these two types help minimize the likelihood of later discovery of the entropy data and thus, compromising of the keys generated using the entropy data. Preferably, two or more sources of entropy data are utilized and then combined, and even more preferably, those sources are independent data sources that provide unrelated data, meaning that that data sources are not controlled by the embedded processing device itself (they are independent of it) and that the data from the different sources are independent of each other (they are unrelated to each other). This helps increase the randomness of the combined entropy data being used and helps prevent later discovery of the data. The data can be combined in simple ways, such as by concatenation of the data, or in more complex manner, such as by applying a cryptographic hash function (for example, a SHA-1 function) to the combined data.

**[0036]** For the vehicle example shown in FIG. **1**, examples of entropy data that can be used are measured transient events occurring on the vehicle, such as features of messages or other

communications occurring on the communications bus **44**, data from a vehicle system module (VSM) **42** such as data from a sensor **43**, or GPS satellite time data (normally used for determining location coordinates) that are received from the GPS module **40**. Other, non-transient, but unique data can be used as entropy data, such as serial numbers from onboard devices, the vehicle VIN, an assigned mobile number for the telematics unit or network node address. Other such sources of entropy will become apparent to those skilled in the art.

**[0037]** Where, as is often the case, the embedded processing device is manufactured as a separate item by one company or organization and then assembled or otherwise installed in the manufactured item by another company or organization, it is preferable to have a portion of the entropy data come from each of these two sources. This helps minimize the possibility that the keys can be compromised since no one source is likely to know all of the entropy data used to generate the keys. In the vehicle telematics example, a supplier of the telematics unit module can include in the module an entropy buffer containing one source of entropy data, such as any of a number of the different examples of entropy data described above. Then, after the telematics module has been supplied to the automotive company that produces the finished vehicle, a second source of entropy data can be added by the automotive manufacturer. Again, either or both of these steps can be carried out automatically by the telematics unit programming when it is powered up. Once both pieces of entropy data are obtained by the telematics unit, it combines them in any suitable fashion as noted above. Thus, using this approach, the manufacturer of the embedded processing device will not itself be able to recreate the keys, and this approach can also be used to prevent the manufacturer of the end product from being able to recreate the keys.

**[0038]** Using the entropy data, the next step **106** in the process is generation of the cryptographic keys using the PRNG within the embedded device. Suitable PRNG software programs are known and can be incorporated into the embedded processing device. The entropy data is used as a seed value for the PRNG, which will yield a nearly random number suitable for use in generating strong cryptographic keys. Once the keys have been generated, the entropy data used to seed the PRNG process is preferably erased from any memory in which it had been held. The use of the output of the PRNG to generate various types of keys is known, including asymmetric public-private key pairs. These keys can be used either in a web of trust scheme, or can be utilized using public key infrastructure wherein the public key can be issued by a certificate authority.

**[0039]** For public-private key pairs, once the keys are generated, the private key is stored in the manufactured product, such as in memory included within the embedded device. This is shown at step **108**. Then, the public key is transmitted electronically (for example, wirelessly) from the manufactured product and stored in an external database, step **110**. A unique ID of the manufactured product or its embedded device can also be stored in the database and associated with the public key so that subsequent communications can be targeted individually to that particular product. For example, a serial number or MAC address for the embedded device can be used. At this point, the generation of the keys is complete and the manufactured product can be distributed by, for example, transferring possession of the product to another entity.

**[0040]** Turning now to FIG. **3**, there is shown a second embodiment **200** of a method for producing cryptographic keys, with this method being directed more specifically to a vehicle application, wherein the keys are used for communicating wirelessly with a telematics unit of the vehicle. The vehicle electronics **28** shown in FIG. **1** and, particularly, the telematics unit **30** can be used to carry out this method. The first step is to manufacture the vehicle **12** at step **202** including its vehicle electronics **28** with the telematics unit **30** being installed as original equipment, as indicated at step **204**. Then, as a part of the initialization of the telematics unit at step **206**, the cryptographic key generating process is begun which first involves obtaining the entropy data at **208**. Preferably, both the gathering of entropy data and the key generation is carried out under control of the telematics unit **30** and, in particular, by the telematics unit processor **52**. As discussed above, a variety of different data sources can be used for the entropy data. This can include one or more of the following sources shown in FIG. **3**; namely, GPS time data obtained from one or more GPS satellites **60**, the vehicle VIN, a serial number for the telematics unit **30** or other VSM **42**, or sensor data such as from the vehicle sensor **43** shown in FIG. **1**. These data sources are mostly external to the telematics unit (embedded device), but not to the vehicle (manufactured product). However, in other embodiments, data external to both can be used, and such data can be obtained either via a wired connection to the vehicle or wirelessly via, for example, the telematics unit and its cellular chipset, or using some other wireless technology. Thus, entropy data of a more truly random nature can be supplied to the vehicle from the manufacturer as a part of initially configuring the telematics unit with its cryptographic keys. However obtained, this entropy data, if from more than one source, is combined at step **210** using any of the techniques discussed above in connection with FIG. **2**.

**[0041]** As shown in FIG. **1**, the telematics unit includes a PRNG program (PRNGP) **55** which can be stored in the telematics memory **54** and executed by the processor **52**. Thus, at step **212**, the PRNG can be seeded with the entropy data and the near-random number that is generated is then used in a known manner at step **214** to generate a public-private key pair. The private key is stored in the vehicle, such as in the telematics memory **54** at step **216**, and the public key is transmitted at step **218** to an external database along with at least one unique identifier associated with the telematics unit. Transmission of the public key can be done wirelessly using the cellular chipset **50** or using some other communication approach, as will be known to those skilled in the art. The external database that stores the keys and associated IDs can be, for example, database **84** that is maintained at the call center **20**. Once the keys have been generated and stored in their respective locations, the vehicle can then be distributed to a dealer or end customer, as indicated at step **220**. The keys can then be used to establish secure communication between, for example, the call center **20** and the vehicle **12**.

**[0042]** For the vehicle telematics unit **30**, because of its wireless data communication capability with the call center **20** and other remote facilities, the key generation process can be carried out automatically without any human initiation or intervention. Thus, for example, the method can be a part of an initialization or setup routine that is automatically run by the telematics unit prior to its use in service. This automatic, self-generation feature of the illustrated embodiment, in conjunction with the act of performing the process prior to relin-

quishing possession to an end user, allows a complete database of keys and vehicles to be automatically set up and populated as a part of the manufacturing stage.

**[0043]** It is to be understood that the foregoing is a description of one or more preferred exemplary embodiments of the invention. The invention is not limited to the particular embodiment(s) disclosed herein, but rather is defined solely by the claims below. Furthermore, the statements contained in the foregoing description relate to particular embodiments and are not to be construed as limitations on the scope of the invention or on the definition of terms used in the claims, except where a term or phrase is expressly defined above. Various other embodiments and various changes and modifications to the disclosed embodiment(s) will become apparent to those skilled in the art. All such other embodiments, changes, and modifications are intended to come within the scope of the appended claims.

**[0044]** As used in this specification and claims, the terms "for example," "for instance," "such as," and "like," and the verbs "comprising," "having," "including," and their other verb forms, when used in conjunction with a listing of one or more components or other items, are each to be construed as open-ended, meaning that that the listing is not to be considered as excluding other, additional components or items. Other terms are to be construed using their broadest reasonable meaning unless they are used in a context that requires a different interpretation.

**1**. A method of producing cryptographic keys for use in communicating with a manufactured product having an embedded processing device, comprising the steps of:

(a) providing a manufactured product having an embedded processing device that includes a pseudo random number generator;

(b) obtaining entropy data;

(c) generating public and private cryptographic keys using the pseudo random number generator and the entropy data;

(d) storing the private key within the manufactured product;

(e) transmitting the public key from the manufactured product for storage in a database external to the manufactured product; and

(f) transferring possession of the manufactured product to another entity.

**2**. The method of claim **1**, wherein the manufactured product is an automobile and the embedded processing device is a telematics unit installed in the automobile as original equipment.

**3**. The method of claim **1**, wherein steps (b) through (d) are carried out prior to step (f) as a part of an initialization routine for the embedded processing device.

**4**. The method of claim **1**, wherein step (b) further comprises obtaining data from at least one independent data source accessible by the embedded processing device.

**5**. The method of claim **4**, wherein the independent data source comprises a vehicle system module.

**6**. The method of claim **5**, wherein the obtained data comprises a sensor reading obtained from the vehicle system module.

**7**. The method of claim **5**, wherein the obtained data comprises a time value.

**8**. The method of claim **5**, wherein the obtained data comprises a unique identifier obtained from the vehicle system module.

**9**. The method of claim **1**, wherein step (b) further comprises generating the entropy data by obtaining data from a plurality of data sources accessible by the embedded processing device and combining the obtained data together.

**10**. The method of claim **9**, wherein the step of combining the obtained data further comprises performing a cryptographic hash function on the obtained data.

**11**. The method of claim **1**, wherein step (e) further comprises transmitting the public key along with a unique identifier for the embedded processing device.

**12**. The method of claim **11**, wherein the unique identifier is a MAC address associated with the embedded processing device.

**13**. The method of claim **11**, wherein the unique identifier is a serial number associated with the embedded processing device.

**14**. A method of producing cryptographic keys for use in communicating with a vehicle having an installed telematics unit, comprising the steps of:

(a) manufacturing a vehicle, including the step of installing a telematics unit in the vehicle such that the telematics unit is in communication with one or more vehicle system modules;

(b) obtaining entropy data under control of the telematics unit by collecting unrelated data from at least two different data sources;

(c) seeding the pseudo random number generator within the telematics unit with the entropy data;

(d) generating public and private cryptographic keys using the pseudo random number generator;

(e) storing the private key within the vehicle;

(f) transmitting the public key to an external database along with at least one unique identifier associated with the telematics unit; and

(g) distributing the vehicle.

**15**. A vehicle electronics system for self-generating cryptographic keys used for secure wireless communication with the vehicle, comprising:

a telematics unit having a processor, memory, and a cellular chipset, wherein said processor executes instructions stored in said memory and controls wireless communication of cellular voice and data calls via said cellular chipset;

a communications bus connected to said telematics unit; and

a plurality of vehicle system modules, at least some of which are connected to said communications bus such that said telematics unit can receive data from said connected vehicle system modules;

wherein said telematics unit includes a pseudo random number generator and is operable under control of said processor to obtain entropy data from at least one independent data source external to said telematics unit and to generate cryptographic keys using said pseudo random number generator and said entropy data.

**16**. A vehicle electronics system as defined in claim **15**, wherein said at least one independent data source comprises at least one of said vehicle system modules.

**17**. A vehicle electronics system as defined in claim **16**, wherein said entropy data comprises at least in part sensor data obtained from one of said vehicle system modules.

**18**. A vehicle electronics system as defined in claim **16**, wherein said entropy data comprises at least in part a unique identifier obtained from one of said vehicle system modules.

**19**. A vehicle electronics system as defined in claim **15**, wherein said telematics unit is operable under control of said

processor to obtain unrelated data from at least two independent data sources, at least one of which is external to said telematics unit.

**20**. A vehicle electronics system as defined in claim **15**, wherein said cryptographic keys include a public key and a private key and wherein said telematics unit is operable under control of said processor to save said private key in memory and transmit said public key wirelessly via said cellular chipset.

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