

EFFICIENT AND RELIABLE DATA TRANSMISSION FOR CELLULAR-AND-GPS-BASED MAYDAY SYSTEMS

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ABSTRACT

As automotive mayday systems continue their momentum to reach the worldwide market, more and more people begin to aware the benefit of these systems. A mayday system could significantly improve the safety of the vehicle and its occupants as well as provide a variety of valuable assistance to its users. Some popular systems integrate a cellular phone with a GPS (Global Positioning System) receiver as their in-vehicle equipment. When activated by a user or an emergency event, the system connects its user instantly to an operator in a 24-hour service center over the wireless cellular network. Meanwhile, the current vehicle position along with other important vehicle information are also transmitted to the center for immediate attention and further process. It becomes very important for mayday system designers to make sure that these data are transmitted efficiently and reliably. In this paper, we will discuss a solution that provides such efficiency and reliability.

1. INTRODUCTION

Data transmission for automotive mayday systems over popular analog cellular networks [1,7] during a handoff is vital for the vehicle to receive proper assistance promptly. In contrast to previously known solutions, this paper presents a subscriber unit (or mobile device)

solution. As will be seen in the following discussion, this new method is much more efficient and reliable than previously known methods. This same method can be further expanded to other location and navigation systems, even hand-held mobile devices, using an analog cellular network as their communications medium.

In the next section, we introduce a typical mayday system and its cellular communications medium. While indicating a drawback of the current mayday system implementation, we present a much better subscriber-unit-based solution to remedy such drawback.

2. DESCRIPTION

A mayday system provides vehicle occupants instant connection with a service center for attention or assistance, in addition to automatically reporting the vehicle position. Many people consider this a necessary service. In particular, most travelers in the United States view this system as their top priority when adding new equipment to their vehicles. Besides emergency services and roadside assistance with location, it can be expanded to include many other services such as remote door unlocking, theft detection, notification and stolen-vehicle tracking, airbag deployment notification, route guidance, travel information, and hands-free and voice-activated mobile phone or pager.

A typical mayday system unitizes a global positioning system (GPS) receiver for positioning and an analog cellular phone for voice and data communications, such as General Motor's OnStar and Ford's RESCU [5,9] as well as many other systems [4,6,8]. An individual mayday system does not need to communicate with the remote host on a regular basis as most automatic vehicle location (AVL) systems do, so there is no need for a high communications bandwidth. For increased security and reliability, the system can be activated either by the user or by an emergency event detected by one of the vehicular safety sensors. The communications channel is established only at this moment. One such system is activated by either of the two buttons in the overhead console. A tow-truck button initiates a roadside assistance call and an ambulance button initiates an emergency call.

Once a button is pressed, a warning light located in the overhead console begins to flash. Status messages are then shown on a multi-function display of an instrument cluster. The

cellular phone in the vehicle automatically places a call to the service center. Immediately after the communications channel is established, the system sends the vehicle identification number (VIN) and position information obtained from an on-board GPS receiver to the host via the voice channel of the cellular phone network and preferably confirms the vehicle location using a map provided by a map database in the service center. If required, the service center operator may maintain direct voice contact with the driver until help arrives and can also notify designated family contacts in an emergency. When roadside assistance is requested, the center can provide an estimated time of arrival and can call back to confirm that the problem has been resolved.

Typical mayday on-board equipment consists of a microcontroller, a GPS receiver, a cellular transceiver, a data modem, and other control circuits as shown in Figure 1. As we see from the above discussion, once the communications channel is established, the system must first send data over the cellular network via

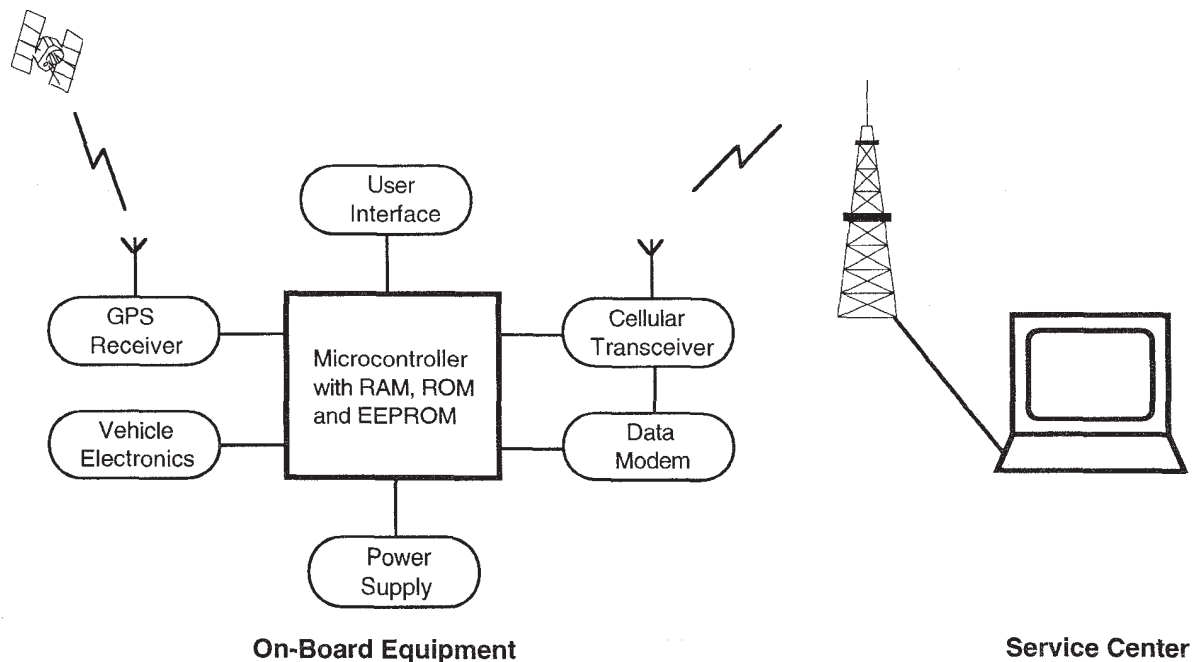


Figure 1 Cellular-and-GPS-Based Mayday System

a modem through the cellular transceiver. These data include information identifying the vehicle and customer, nature of the request, and GPS position (coordinates in the surface of the Earth). Upon receiving these data, the service center will convert the GPS coordinates to a local map grid, contact the proper service providers and direct them to the vehicle. For instance, in a medical emergency, the service center will contact the nearest 911 public safety answering point (PSAP) and dispatch an ambulance. For a vehicle breakdown, a designated roadside service provider is notified and a tow-truck is dispatched. Without these data, it is very difficult to timely locate the caller and obtain vital information. Therefore, the data sent over the wireless communications channel must be reliable.

During the data transmission, special attention must be paid to one particular aspect of reliability problem, e.g., the potential problem of losing crucial data while the vehicle is moving. In general, vehicles move much faster than human beings. Therefore, the situation is more brutal in moving vehicles than a slow-paced person carrying a cellular phone. To understand this problem better, let us look at how the cellular network operates under this circumstance.

Each coverage area in the cellular network is divided into cells which are usually 1 to 20 miles (or 1.6 to 32.2 kilometers) in diameter. Each cell is operated via a base station, typically located at the center of the cell, under the supervision of a cellular radio telephone exchange, called mobile switching center (MSC). MSC is linked into the public switched telephone network (PSTN). Adjacent cells use different frequencies to avoid overlap. Once a caller's cellular transceiver is turned on and within the range of a particular cell, its link to the network can be established and controlled via its base station. When a mobile caller moves from cell to cell, handoff (or handover

in Europe) to a different base station in an adjacent cell occurs automatically to avoid interrupting the call or altering the user. When the mobile unit moves out of the coverage area of a particular cell, the signal reception over the mobile unit becomes weak. The weaker signal could be the result of the mobile unit reaches the cell boundary or the signal-strength gap within the cell. At this point, the current cell site requests a handoff. The system then switches to a different cell site automatically.

During the whole handoff process, the supervisory audio tone (SAT) signal plays an important role on the final handshaking or call set-up operation [1,2]. From an example in Figure 2, we can see that during the handoff there is a brief period that the communications channel will be unavailable, as the cellular system seizes this moment to transmit a burst of data on that channel. Consequently, the cell site stops sending SAT to the subscriber unit. Once the subscriber unit detects the loss of SAT, it immediately mutes the audio to permit the reception of the burst of data containing the handoff order sent by the cell site. After receiving the handoff order, the subscriber unit replies to the cell site by sending a burst of signaling tone (ST). The subscriber unit then turns off the transmitter from the original voice channel and switches to the new voice channel. From this new channel, the subscriber unit receives the new SAT. If the newly received SAT is the same as the SAT received from the handoff order, it transmits the SAT back to the new cell site. After the new cell site receives the SAT, it reports to an MSC that the subscriber unit has successfully switched to the new voice channel. The MSC drops the original voice channel and completes the handoff process. For more information about the cellular handoff process and its solutions, refer to [1,2,3,7].

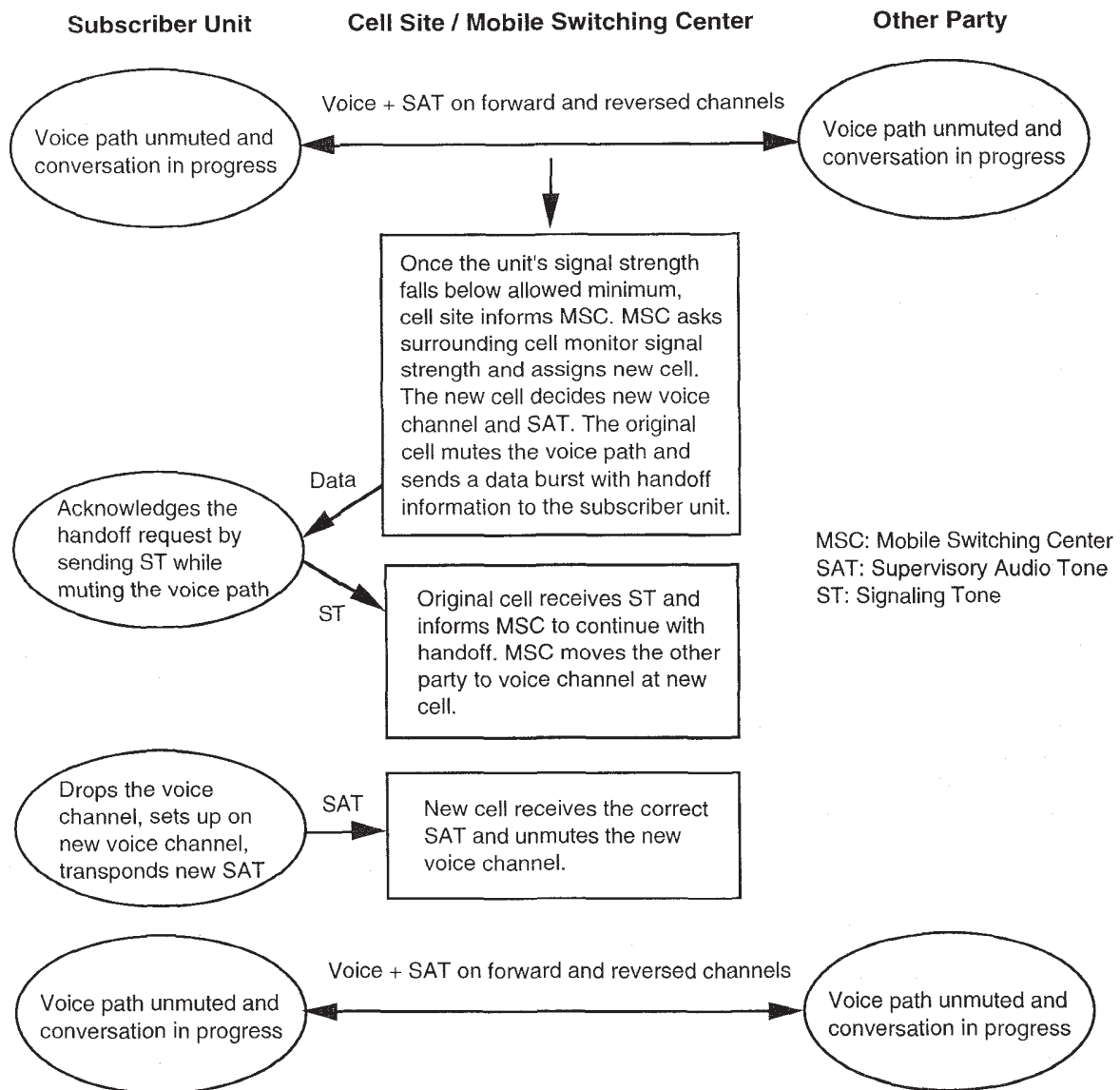


Figure 2 Analog Cellular Handoff Process

A potential problem occurs when the mayday user needs to make an automatic call during the cellular handoff because of the temporary unavailability of the communications channel. The data sent to the service center are crucial for the operator to locate the vehicle and for fast responses of the service provider. Unlike voice communications where a user does not care if a syllabus or two is lost in a conversation, an emergency data message cannot afford to lose even a single byte. The current system relies on the equipment at the service

center to detect the situation. If the data fail to reach the center or are corrupted, a message will be sent to the on-board system requesting that the data be sent again. This message is usually repeated three times to make sure the on-board system re-transmits the data. This request message is sent over the same communications channel used in the handoff process. This will not only delay the response time of the on-board system, but also force the message to go over the air (wireless medium) again.

A more efficient and reliable solution is to trigger the data re-sending process by the subscriber unit itself within the on-board equipment, rather than via the service center equipment remotely over the air. In this way, many uncertain factors during the retrying process have been eliminated. During the cellular handoff process, the subscriber unit knows exactly when the handoff process is done, that is, when it transmits a new SAT to a new cell site. After this step, the subscriber unit can signal the on-board mayday system right away to request the re-transmission of the emergency data. Clearly, this new solution is better and could also be used in other location and navigation systems or mobile devices which use the analog cellular network as their data communications medium.

The new solution proposed in this paper does not need to add any hardware equipment to the subscriber unit, service center or cell site. It is a software solution, which simply moves the error detection and correction responsibility from the service center to the subscriber unit. In doing so, it eliminates an additional error source of allowing critical retrying messages going through the air. On the other hand, this solution could be difficult to realize if the subscriber unit used in the mayday system is manufactured by a third party and is not accessible to the mayday system producer and provider.

3. CONCLUSION

The main advantage of the automotive mayday system is its ability to provide emergency help to their mobile users with a touch of a button or a trigger of an emergency event. A request for re-transmitting lost or corrupted emergency data during the emergency call process is commonly handled by the retrying message generated by the service center equipment over the air. A simpler and better subscriber-unit-based solution is proposed in this paper, which will make data re-transmission more efficient and reliable. De-

playing such technique can boost consumer's confidence in future mayday systems. With this new solution, the advantage of the mayday system will be further strengthened.

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