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Time Synchronization Possibilities in Wireless networks for Embedded Systems

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Abstract: The utilization of embedded systems grows from year to year. Embedded systems are used almost in each electronic or electromechanic device utilized by people and they often do not realize it. When connecting such embedded systems to a network, the system can exchange variety of useful information with the network and other embedded systems. Time synchronization represents a delegate of such information exchange. This paper focuses on possibilities of time synchronization of embedded systems over wireless networks.

Key-Words: GSM, GPS, WLAN, Time synchronization, Protocol, Embedded system

1 Introduction

The popularity of embedded systems grows from year to year and they become still larger field of utilization. Not only mobile phones, mobile computers, and PDA's utilize computer based microprocessors with huge possibilities, but the embedded systems are utilized almost in each electronic or electromechanic device. Cars, airplanes, dishwashers, coolers, that are only few candidates where embedded systems are utilized.

As the utilization of computer based embedded systems grows, so do mobile networks and internet. The embedded systems are still oftener connected to some type of global network, either fixed or mobile. This connection facilitates the exchange of information between the embedded system and the network, or between particular embedded systems.

This paper focuses on research of possibilities how to exchange time synchronization information between particular embedded systems among some type of wireless network. The contribution deals with widely utilized wireless network, such as GSM, GPS, and WiFi.

2 Motivation

The exact time synchronization of embedded systems can be useful in many practical cases where the embedded systems interact with each other. One of these cases is for constructing black-boxes for cars. In the control unit of the car can be found almost all information about the current state of the car, such as speed, direction, status of the electronics in the car, etc. When an accident happens, when the collided cars are synchronized in time, we can precisely reconstruct their behavior and status in the past few minutes and so decide which of the drivers is responsible for the accident.

The black-box for cars is only one useful application of time synchronization between embedded systems. Many other applications can be found, but it is not the topic of this paper.

3 Global System for Mobile Communications - GSM

In a GSM network, there are three functional areas: the Mobile Station such as a mobile phone or an embedded system which is carried by a subscriber, the Base Station Subsystem which controls the radio link with the Mobile Station, and the Network Subsystem which mainly performs the switching of calls between the mobile users, and between mobile and fixed network users.

The signalling protocol in GSM is structured into three general layers, depending on the interface, as shown in the following figure. Layer 1 is the physical layer, which uses the channel structures discussed above over the air interface. Layer 2 is the data link layer. Across the Um interface, the data link layer is a modified version of the LAPD protocol used in ISDN, called LAPDm. Across the A interface, the Message Transfer Part layer 2 of Signalling System Number 7 is used. Layer 3 of the GSM signalling protocol is itself divided into 3 sublayers:

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Radio Resources Management

The radio resources management (RR) layer oversees the establishment of a link, both radio and fixed, between the mobile station and the MSC. The main functional components involved are the mobile station, and the Base Station Subsystem, as well as the MSC. The RR layer is concerned with the management of an RR-session, which is the time that a mobile is in dedicated mode, as well as the configuration of radio channels including the allocation of dedicated channels.

Mobility Management

The Mobility Management layer (MM) is built on top of the RR layer, and handles the functions that arise from the mobility of the subscriber, as well as the authentication and security aspects. Location management is concerned with the procedures that enable the system to know the current location of a powered-on mobile station so that incoming call routing can be completed.

Connection Management

The Communication Management layer (CM) is responsible for Call Control (CC), supplementary service management, and short message service management. Each of these may be considered as a separate sublayer within the CM layer. Call control attempts to follow the ISDN procedures specified in Q.931, although routing to a roaming mobile subscriber is obviously unique to GSM. Other functions of the CC sublayer include call establishment, selection of the type of service (including alternating between services during a call), and call release.

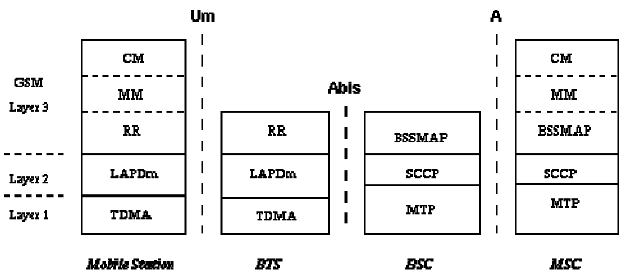

Figure 1: Signalling protocol structure in GSM

Time synchronization between the mobile device and the base station is necessary for correct communication and message passing between particular elements of the network. Therefore, each BTS stores accurate time information and utilizes this information for logging. Unfortunately, the time information is not passed to the mobile devices, the synchronization between the BTS and the mobile device is performed utilizing synchronization bits. Therefore, when time information should be send, it is necessary to utilize a GSM's network capability to send messages among all mobile devices – the cell broadcast messages.

Cell broadcast messages are utilized by network providers to send information to customers in the form of SMS. Such message is delivered to all registered mobile devices in particular area, whereas the provider may decide in which location will be the message broadcasted. This mechanism of message broadcasting can be utilized for broadcasting accurate time information. Because the broadcast messages can not be sent continuously, the time information can be transmitted only in given intervals. Therefore, the embedded systems utilizing such method of time synchronization must have internal clocks which synchronize with the sent information. The duration of the interval depends on the providers capabilities. Too short interval would rapidly increase the network load, whereas too large interval would lead to inaccuracy.

4 Global positioning System - GPS

The Global Positioning System (GPS) is a space-based radionavigation system which is managed for the Government of the United States by the U.S. Air Force (USAF), the system operator. GPS was originally developed as a military force enhancement system and will continue to play this role. However, GPS has also demonstrated a significant potential to benefit the civil community in an increasingly large variety of applications. In an effort to make this beneficial service available to the greatest number of users while ensuring that the national security interests of the United States are observed, two GPS services are provided. The Precise Positioning Service (PPS) is available primarily to the military of the United States and its allies for users properly equipped with PPS receivers. The Standard Positioning Service (SPS) is designed to provide a less accurate positioning capability than PPS for civil and all other users throughout the world.

Besides determining the precise 3D position of the GPS device, GPS satellites transmit accurate time information. GPS time is established by the Control Segment and is used as the primary time reference for all GPS operations. GPS time is referenced to a UTC (as maintained by the U.S. Naval Observatory) zero time-point defined as midnight on the night of January 5, 1980/morning of January 6, 1980. The largest unit used in stating GPS time is one week, defined as 604,800 seconds. GPS time may differ from UTC because GPS time is a continuous time scale, while UTC is corrected periodically with an integer number of leap seconds. There also is an inherent but bounded drift rate between the UTC and GPS time scales. The

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GPS time scale is maintained to be within one microsecond of UTC (Modulo one second). The navigation data contains the requisite data for relating GPS time to UTC.

In each satellite, an internally derived 1.5 second epoch provides a convenient unit for precisely counting and communicating time. Time stated in this manner is referred to as a Z-count. The Zcount is provided to the user as a 29-bit binary number consisting of two parts as follows:

1) The binary number represented by the 19 least significant bits of the Z-count is referred to as the time of week (TOW) count and is defined as being equal to the number of 1.5 second epochs that have occurred since the transition from the previous week. The count is shortcycled such that the range of the TOW-count is from 0 to 403,199 1.5 second epochs (equaling one week) and is reset to zero at the end of each week. The TOW-count's zero state is defined as that 1.5 second epoch which is coincident with the start of the present week. This epoch occurs at (approximately) midnight Saturday night-Sunday morning, where midnight is defined as 0000 hours on the Universal Coordinated Time (UTC) scale which is nominally referenced to the Greenwich Meridian. Over the years, the occurrence of the "zero state epoch" may differ by a few seconds from 0000 hours on the UTC scale, since UTC is periodically corrected with leap seconds while the TOW-count is continuous without such correction.
2) The ten most significant bits of the Z-count are a binary representation of the sequential number assigned to the present GPS week (Modulo 1024). The range of this count is from 0 to 1023, with its zero state being defined as that week which starts with the 1.5 second epoch occurring at (approximately) midnight on the night of January 5, 1980/morning of January 6, 1980. At the expiration of GPS week number 1023, the GPS week number will rollover to zero (0). Users must account for the previous 1024 weeks in conversions from GPS time to a calendar date.

The time information send by the GPS satellites is very accurate (in range of 300ns) and is very suitable for embedded system's synchronization. Unfortunately, for receiving the GPS signal is a clear view on the sky necessary, therefore, time information would never reach embedded systems permanently hidden inside buildings. Moreover, the receivers of GPS signals are more expensive than the GPS receivers. Furthermore, the receiving embedded system must be equipped with internal clock like in the GPS case because of the possibility of signal lost inside buildings.

5 Wireless LANs - WiFi

WiFi is considered a generic term that refers to the IEEE 802.11 communication standards for wireless local area networks. WiFi technology has been developed as an alternative to connecting networked devices by using Ethernet cables. When replacing Ethernet cables with WiFi adapters, the network can be connected quickly, easily and without the limitation of wires. On the other hand, in contrary to the GSM wireless communication, WiFi has rapidly shorter communication range counting up maximally to hundreds meter.

Because the WiFi is a Ethernet based computer network, the time synchronization can be performed by standardized network time synchronization, such as Network Time Protocol (NTP). The communication utilizes TCP/IP communication protocol which is in many cases included directly in the embedded system. Therefore, the embedded system needs to be extended only by the WiFi receiver. Disadvantage of this technique is the short signal range.

6 Time Broadcasting Radio Stations

In some locations of the world, a special radio stations exists which continuously broadcast time information. Such station transmits at particular frequency a special radio signal containing the information about current time. The embedded system has to be equipped with a classical radio receiver tuned on the appropriate frequency and with a demodulation circuit which decodes the time information from the analog signal. This variant of time synchronization is the cheapest one from the presented possibilities and the radio signal has wide range, unfortunately, the signal is in each region transmitted on particular frequency and in different format. Therefore, the embedded system would be usable only in the specific region. When traveling across the ocean, the time synchronization would not work.

7 Conclusions

The usage of embedded systems grows from year to year. Moreover, with the successful expansion of internet and networking generally, the embedded systems are often connected to some type of network. The embedded systems communicate among these connections with the network or with other embedded devices. The communication is often performed only in a simplex mode, i.e. the embedded system either only transmits information or only receives information.

This contribution deals about simplex communication possibility of embedded systems, precisely about receiving accurate time information from wireless networks. The knowledge of accurate time can then be utilized to synchronize behavior of particular embedded systems, for example as a black-box for cars.

The paper describes four possibilities, how to receive time information among wireless networks. The first utilizes GSM networks, where the time information has to be send among cell broadcast messages. Second possibility utilizes the GPS system which transmits the accurate time all over the world, unfortunately, the system is useless for embedded systems inside buildings. The third approach utilizes common Wireless LANs, which can utilize standardized protocols, unfortunately they have short signal range. The last technique receives the time information from special radio stations, but the stations are not standardized and transmit on particular frequencies in particular formats.

Further development will be oriented on the utilization of the time synchronized embedded systems, precisely on the black-box for cars to help solve accidents.

8 Acknowledgement

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