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The Location Measurement Unit (LMU): An Application of Embedded Systems in Mobile Location Estimation

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Abstract: Embedded systems are commonly available in many electronic devices where they add special functionalities, features and high levels of efficiency to the general operation of these devices. Embedded systems consist of hardware, software, and an environment. The hardware comprises mainly the processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic of these systems, however, is being dedicated to handle a particular task. Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. This paper takes a deep look into the procedures for the design of embedded systems and the fields of application of these systems, with a special emphasis on a mobile network entity called the Location Measurement Unit (LMU) which is used for location measurements in 3G wireless networks.

Key words*: Embedded systems, microcontrollers, processors, RTOS, LMU*

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INTRODUCTION

Advancement in technology has been consistent over the years, leaving many challenges to the old ways of doing things in its wake. Locating the position of a mobile user is one issue that has had a strong challenge in the face of advancements in wireless technology. There are many applications that make use of this information to provide essential and value added services to mobile users. The basic objective of this paper is to take a detailed look at the entity, LMU, which is an embedded system found in the 3G wireless networks with a specific function of measuring signal parameters used in location estimation.

Significant advances in microelectronics technology made the increasing miniaturization of electronic systems possible. The trend is leading to and will result in the development of tiny embedded systems, integrated into more and more everyday objects, machines and electronic devices, and will create a world of smart devices surrounding us [1].

EMBEDDED SYSTEM – WHAT IS IT?

Definition: It is defined as an application specific, organized hardware, controlled by specific software in which the hardware and software are the components of the embedded system. One way of looking at an embedded system is that the mechanisms and their associated I/O are largely defined by the application. Then, software is used to coordinate the mechanisms and define their functionality, often at the level of control system equations or finite state machines [2]. Finally, computer hardware is made available as infrastructure to execute the software and interface it to the external world. Embedded systems have special features that tell them apart from the device they are part of. These features of an embedded system are listed below [3].

- It is application specific: Embedded systems are application specific & single functioned; the application is known form onset, the programs are executed repeatedly. An increasing number of embedded systems today use more than one single processor core to enable them increase the range of functions they can perform.
- It is embedded: "Embedded" reflects the fact that it is *embedded* as part of a complete device often including hardware and mechanical parts.
- Designed to function in real time: Some also have real-time performance constraints that must be met, for reasons such as safety and usability; others may have low or no performance requirements, allowing

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the system hardware to be simplified to reduce costs

- It could be standalone system or part of a larger system
- Embedded systems often interact (sense, manipulate & communicate) with external world through sensors and actuators and hence are typically reactive systems.
- They generally have minimal or no user interface.
- They are not flexible: By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. This means that the system is only able to run a single application.

The major building blocks of an Embedded System

- Microcontroller/microprocessor: Embedded systems contain processing cores that are either microcontrollers, or digital signal processors (DSP).
- Timers, memory and whatever is needed for running the specific task
- Software: The program instructions
- Real time operating system (RTOS), including board support package and device drivers. A real-time operating system (RTOS) is an operating system that guarantees a certain capability within a specified time constraint
- Printed circuit board assembly and integrated chips
- Interfaces: Embedded systems range from no user interface at all — dedicated only to one task — to complex graphical user interfaces that resemble modern computer desktop operating systems. [4]

FIELDS OF APPLICATION OF EMBEDDED SYSTEMS AND EXAMPLES

Physically, embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, and largely complex systems like hybrid vehicles, MRI, and avionics. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

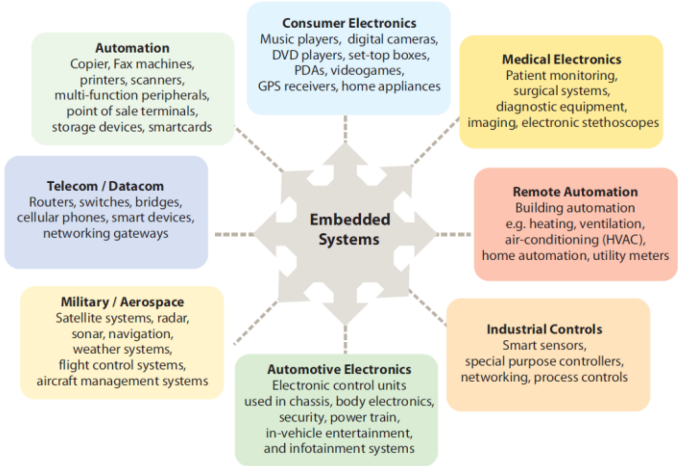

Fig 1: fields of application of Embedded systems [5]

THE LMU: AN EMBEDDED SYSTEM AND ITS APPLICATION IN MOBILE LOCATION ESTIMATION

The manufacture of mobile telecommunication equipments is a typical field for the deployment of embedded systems design. Such equipments are made up of various embedded systems which perform specific and dedicated functions that add together to realize the overall communication goals of the equipment. The Location Measurement Unit (LMU) is one of such embedded systems. It is an entity found in 3G wireless networks which makes measurements (e.g. of radio signals) and communicates these measurements to a Radio Network Controller (RNC) for use in locating the position of a mobile device. [6]

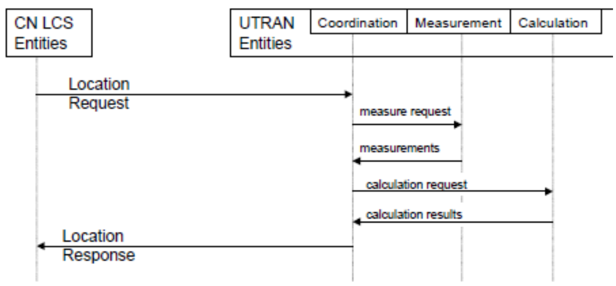

Fig 2 general sequence for UE positioning operation

Functions

The Radio Interface Timing functionality in the LMU should be capable of performing the following functions:
- The LMU performs necessary radio interface measurements from signals transmitted by Node Bs;
- If the LMU contains a common reference clock, e.g. GPS TOW, it time stamps reception of Node B signals by performing measurements of UTRAN GPS timing of cell frames;

- If there is no reference clock available, the LMU may make SFN-SFN Observed Time Difference or measurements, i.e. measures the time difference between arrival of SFNs from neighbouring Node Bs and a reference Node B;
- The LMU may perform some processing of measurements, like averaging and filtering, using parameters delivered to it, or in their absence using default settings.

The results of the measurements by the LMU include:

- Roundtrip delay estimates in connected mode;
- The geographic position co-ordinates of the neighbouring Node B;
- The idle period places within the frame structure for multiple cells;
- The local time-of-day;
- SFN-SFN Observed Time Difference of the signals transmitted by Node B, where timing differences are measured relative to either some common reference clock (UTRAN GPS timing of cell frames) or the signals of another Node B (SFN-SFN Observed Time Difference);
- Reference time, reference position, DGPS corrections, ephemeris and clock data, and almanac data.

All positioning and assistance measurements obtained by an LMU are supplied to a particular Controlling RNC (CRNC) associated with the LMU.

The CRNC provides the following functionalities:

1. broadcast of system information:

The CRNC broadcasts information in support of the selected positioning method. Such information usually includes the measurements from the LMU. This broadcast information may be specially coded (i.e. encrypted) to ensure its availability only to subscribers of the service.

The information to be broadcast could include, for example:

- Identification and spreading codes of the neighbouring cells (the channels that are used for measurements);
- Relative Time Difference (RTD), i.e. the timing offsets, asynchronicity between base stations, could be based on measurement results obtained by LMUs;
- The local time-of-day;

2. Request UE Positioning related measurements from its associated Node Bs and LMUs:

The measurements requested by CRNC from its associated Node Bs and LMUs is dependent on the positioning method used. The following measurement returned by a LMU to a CRNC has a general status and may be used for more than one positioning method:

- Radio interface timing information

3. Resources management:

Signalling between Node B or LMU and CRNC is transferred using Iub signalling.

Instructions concerning the timing, the nature and any periodicity of these measurements are either provided by the CRNC or are pre-administered in the CRNC (e.g. using O&M). According to the system specification by the 3GPP group, The LMU may make its measurements in response to requests (e.g. from the CRNC), or it may autonomously measure and report regularly (e.g. timing of Node B transmissions) or when there are significant changes in radio conditions (e.g. changes in the UTRAN GPS timing of cell frames or SFN-SFN Observed Time Difference). These measurements may be made either, for example, to locate the UE or to measure a system parameter needed by the UE Positioning such as the timing offset (UTRAN GPS timing of cell frames or SFN-SFN Observed Time Difference) of transmissions Node Bs. There may be one or more LMU associated with the UTRAN and an UE Positioning request may involve measurements by one or more LMU. The LMU may be of several types and the CRNCs will select the appropriate LMUs depending on the UE Positioning method being used.

The LMU may also measure other transmissions, such as those of satellite navigation systems (i.e. GPS) and either report the measurements for use by the CRNC, or report the positioning results as determined by internal calculations of the LMU. The details of the measurements to be made by the LMU will be defined by the chosen UE Positioning method.

The radio measurements made by LMU fall into one of two categories:

(a) Positioning measurements specific to one UE and used to compute its position;

(b) Assistance measurements applicable to all UEs in a certain geographic area.

There are two classes of LMU:

Stand-Alone LMU

A stand-alone LMU is accessed exclusively over the UTRAN air interface (Uu interface). There is no other connection from the stand-alone LMU to any other UTRAN network element.

A stand-alone LMU has a serving Node B that provides signaling access to its CRNC. A stand-alone LMU also has a serving 3G-MSC, VLR and a subscription profile in an HLR. It always has a unique IMSI and supports all radio resource and mobility management functions of the UTRAN radio interface that are necessary to support signaling.

To ensure that a Stand-alone LMU and its associated CRNC can always access one another, an LMU may be homed (camped) on a particular cell site or group of cell sites belonging to one 3G-MSC. All other data specific to an LMU is administered in the LMU and in its associated CRNC.

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Associated LMU

An associated LMU is accessed over the Iub interface from an RNC. An associated LMU may make use of the radio apparatus and antennas of its associated Node B. The LMU may be either a logically separate network element addressed using some pseudo-cell ID, or connected to or integrated in a Node B. Signaling to an associated LMU is by means of messages routed through the controlling Node B.

An associated LMU may be separated from the Node B, but still communicate with the CRNC via the Node B Iub interface.

DESIGN REQUIREMENTS FOR EMBEDDED SYSTEMS

One of the major goals of embedded system designs is compactness. Hence, embedded system vendors mostly adopt microcontrollers. This doesn't mean that microprocessor is less applicable. It is as important as the microcontroller which has its own applications. Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance.

1. Reliability: Embedded systems often reside in machines that are expected to run continuously for years without errors and in some cases recover by themselves if an error occurs.
2. Small size, low weight: Embedded systems have stringent weight and size requirements
3. Safe and reliable: The design challenge here is to ensure continued operation after an equipment failure, with minimum with minimal redundancy
4. Harsh environment: The challenge here is accurate thermal modeling and designing according to operation requirement
5. Cost sensitivity: Even though embedded computers have stringent requirements, cost is almost always an issue (even increasingly for military systems).
6. End-product utility: The utility of the end product is the goal when designing an embedded system, not the capability of the embedded computer itself. The emphasis here is on the total functionality delivered by the end product.
7. Power management: The challenge to designers is to provide ultra-low power design for long-term battery operation.
8. Upgrades: The challenge here is ensuring complete interface, timing, and functionality compatibility when upgrading designs.

DESIGN TOOLS FOR EMBEDDED SYSTEMS

As with other software, embedded system designers use compilers, assemblers, and debuggers to develop embedded system software. However, they may also use some more specific tools [7]:

a. Software tools: Integrated development environment (IDE), Flash programmer, compilers and assembler
b. Workbench: MATLAB/Simulink, MathCAD, Mathematica
c. Real time operating systems (RTOS): Android, DSPnano RTOS, Microcontroller operating systems
d. Debuggers: An in-circuit emulator (ICE), An in-circuit debugger (ICD), A complete emulator, Interactive resident debugging.

SKILLS FOR EMBEDDED SYSTEM DESIGN

Knowledge and skills required in these areas are- Good knowledge in theory and practical of one or two micro controllers like PIC, 8051, or AVR etc. Deep and sound knowledge in programming language – especially embedded C, is also a necessary skill for embedded system designers

They also require a host of diverse skill-sets related to hardware, electronics and mechanical domains, which renders further complexity to their development.

CONCLUSION

Embedded Systems are simply the brain of most of the electronic devices used to access, process, and store and control data received from the environment. Few simple electronics circuits can be intelligently hard-wired and designed without a microprocessor or microcontroller but is not worth the economics except for simple passive operations. Embedded market is experiencing best of its times and double-digit market growth will continue for some more years. It will continue to grow as long as semiconductor ICs are used for data processing. In the case of the Location Measurement Unit, which is a practically implemented example of an embedded system, there is a continuous technological advancement towards providing location information about every user in a wireless network. The LMU is will likely be a key entity in every GSM based wireless network in times to come.

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