Demo: A Long-range High-rate Communication Module for Imote2

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***Abstract*—After a decade of development, Imote2 is becoming a de facto standard for a computer-equipped sensor. Attracted by its wireless feature, an increasing number of applications are now trying to use Imote2 as part of their supporting hardware. These applications range from medicare, structural health monitoring, to building management systems and railway monitoring. Their widely diverse requirements call for Imote2 to equip off-the-shelf modules so that the applications can seamlessly integrate Imote2 into their systems. Conventionally, an Imote2 records sensor readings and sends the data to a base station, i.e., a near-by Imote2 connected to a computer. This requires a computer to be placed in a close range of the Imote2 sensors (usually less than 200 meters). Such mechanism is not universally suitable. Especially, some applications cannot afford to place a computer unattended (e.g., in the field or in an ad hoc location in a building). There are other applications that need high data rate. We develop a long-range high-rate communication module for Imote2. Integrated with our module, the data of an Imote2 can be send to a server anywhere using 3G and the data rate can reach 520K bps.**

In this demo, we will show our enhanced Imote2. We will show videos of a few projects, including high-speed railway monitoring and building management systems, using our enhanced Imote2 based sensor networks.

I. Introduction

We are recently working on two applications: 1) high-speed railway monitoring (HSRM), and 2) building management system (BMS). All these involves using various sensors to monitor the properties of equipments or environment. The development of wireless sensor networks has provided us an attractive wireless choice as part of our monitoring systems.

As a de facto standard, Imote2 [1] is an off-the-shelf, high performance computer-equipped sensor. Many applications (including HSRM and BMS) are attracted because Imote2 has 1) wireless feature, so as to greatly save the deployment effort and cost, 2) front-end computing capability; so as to digitize sensor signals immediately to effectively avoid data loss during transmission (e.g., through re-transmission), and 3) readily to use; rather than design another application specific wireless sensor, Imote2 has advanced hardware and complete software development package and support. The design for Imote2 aims at low power and low rate applications. For a standard wireless sensor network application, an Imote2 will sample the readings of its sensors, and send the results to a base station, which is another Imote2 sensor plugged in a computer near-by. The communication range of Imote2 is less than 200 meters and the transmission rate is 250Kbps (IEEE 802.15.4 standard).

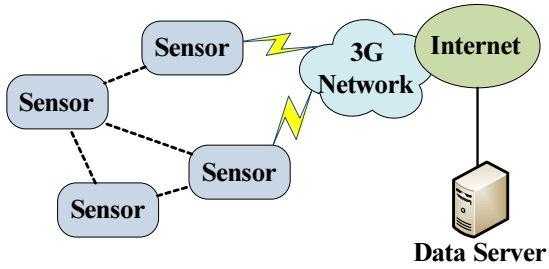


Fig. 1. The architecture of the wireless sensor network using 3G transmission.

A key deficiency for applying Imote2 for our applications is to place a computer unattended in the wild (HSRM) or in an open public room of a building (BMS) for a long time. Many studies advocate multi-hop routing to relay data. Currently multi-hop routing is not mature in performance. Worse, for applications in the wild, such as HSRM, multi-hop routing is not a choice at all.

Some applications also request higher data throughput. For example, for HSRM, the accelerometers generate large volume of data. Though Imote2 has a 250K bps communication rate, the true data stream throughput is usually topped at 100K bps.

II. Design

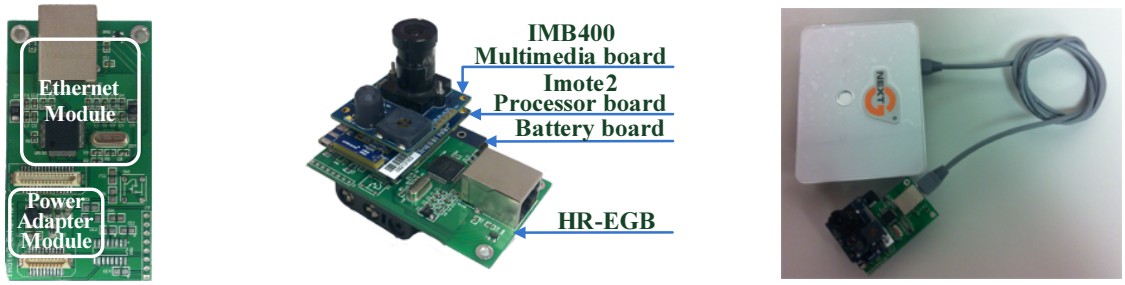
The architecture for our application is shown in Fig. 1. The sensors form a wireless sensor network and some enhanced Imote2 can directly use 3G network to connect to a data server far away. Note that we choose 3G instead of WiFi as 3G is more universally accessible and has potentially larger data rate.

Our key component is a high-rate Ethernet Gateway board, HR-EGB. HR-EGB converts the data from Imote2 node to Ethernet. As such, Imote2 can be directly connected to a 3G router and transmit its data to a remote server.

Fig. 2 (a) shows our High-Rate Ethernet Gateway Board. An integration with Imote2 and a high rate camera sensor is shown in Fig. 2 (b), and the full module for Long-range High-rate Imote2 with a 3G router is shown in Fig. 2 (c).

In principle, the data output of Imote2 must go through a series of conversion so that they can be input into standard Ethernet port. The flow chart of our design is in Fig. 3.

HR-EGB is a separate module which is connected with the Imote2 node through the basic-connector, and it is directly controlled by the Imote2 node. HR-EGB chooses an SPI interface as the communication channel with Imote2 node. It



(a) (b) (c)

Fig. 2. Our Long-range High-rate communication module for Imote2

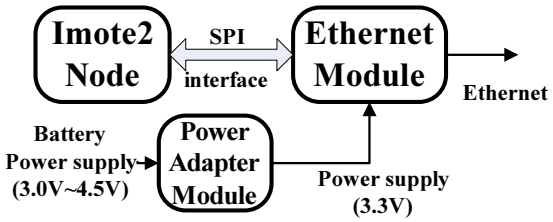


Fig. 3. The components for HR-EGB

has a bit-rate ranging from 6.3Kbps to 13Mbps. This makes our design bypass the throughput bottleneck.

HR-EGB has the following two hardware modules:

1) An ethernet module: HR-EGB applies W5100 as the network chip. W5100 integrates a hardware network stack, offering 4 separate socket interfaces. After simple initialization, developers can use TCP connection or send UDP packet the same as other applications. This choice avoid the high complexity of the network stack and network card driver for the operation system designers, especially for a simple OS like TinyOS. This makes the system simple and stable.

2) A power adapter module: The power adapter module change the battery power supply (3.0V - 4.5V) to a stable 3.3V power supply which is required by our hardware network stack module. We use LTC3429 Micropower Synchronous Boost Converter as the kernel chip for this module. LTC3429 has an up to 96 power conversion efficiency, leading to less power loss during conversion.

We also developed a parallel software program. The essence is that the 1) reading of the sensor input (e.g., the camera data), and 2) sending frames to W5100 buffer and W5100 hardware transmission process can work in parallel. As such, a much higher data rate can be achieved. The pure effective data stream throughput of our module is 520K bps; and we will show in our demo that it can support smooth video streams.

III. Demo Description

There will be three levels for our demos. First we will bring our enhanced Imote2 package and answer questions for our designs. We will show a poster describing the details of our HR-EGB, and our full package as shown in Fig. 2.

Second, we will prepare an Imote2 sensor in Hong Kong and install a server in Shanghai. The Imote2 sensor will transmit data directly from Hong Kong to Shanghai.[1]

Third, we will show some videos of our sensor network equipped with the enhanced Imote2 sensors in use of some applications: 1) in a high-speed railway monitoring application in Nanjing, Jiangsu province, China (part of High Speed Monitoring project) and 2) in a building monitoring application (part of our experiment BMS system in Hong Kong Polytechnic University Campus). Our video shows the following. A server will be placed in The Hong Kong Polytechnic University. This server is a desktop computer and there is no base station attached to this computer. A sensor network is established in a remote field (e.g., Nanjing) where direct communication between the sensors and the computer is not possible. Some sensors in the sensor network will collect such data as accelerations, temperature with the sensors on the ITS400 boards; and one sensor will be equipped with a camera (e.g., Fig. 2 (b)) to record videos in the field. The sensors will self-organize as a network and send the data through a 3G router to the server.

A preliminary version of part of our demo is shown in [2]. In this preliminary version, we established a server on a computer in The Hong Kong Polytechnic University. We brought one of our enhanced Imote2 sensor with camera to take videos from the Victoria Harbor of Hong Kong (in the video, we can see the Hong Kong Convention and Exhibition Centre, Bank of China Tower, and the International Finance Center). The video stream was sent directly from Victoria Harbor to The Hong Kong Polytechnic University. The distance between the two locations is 7.7km [3].

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References

[1] http://docs.tinyos.net/index.php/Imote2
[2] http://www.comp.polyu.edu.hk/~csdwang/Projects/RM-demo.MOV
[3] http://maps.google.com

[1]Our module needs a registration for a 3G plan from a local ISP. We do not plan to register a local 3G in Shanghai. Therefore, we cannot send data from Shanghai to Shanghai. We have 3G registration in Hong Kong, however; and we can send data from Hong Kong to Shanghai.