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Fundamental of IEEE 802.15.4 and Its Application on Vehicular Wireless ADHOC Network

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Abstract

IEEE 802.15.4 is a wireless personal area network and it belongs to IEEE 802 family. The IEEE 802.15.4 is designed for low cost and low power consumption. It is the basis for the Zigbee and MIWI. In this paper we will highlight some of the basic features of IEEE 802.15.4 wireless network protocol and its application on vehicular communication. A vehicular communication is a wireless vehicular adhoc network which allows vehicles to talk to each other and exchanging real time data among themselves. The use of IEEE 802.15.4 in vehicular network has many advantages and the result shows the possibility of avoiding many road accidents by vehicular networking system using low cost IEEE 802.15.4.

Index Terms: IEEE 802.15.4; Mac layer; PHY layer; Vehicular Adhoc Network (VANET); MiWi.

Introduction

Wireless technology has become more and more important in our everyday live. Our dependence on wireless technology is increasing very fast as it enhance and makes our ways of living easier in many aspect. IEEE 802.15.4 is a wireless network protocol developed for low data rate and low power consumption. The IEEE 802.15.4 standards defines the physical layer (PHY) and media access control (MAC) layer of the open system interconnection (OSI) model of network operation. The PHY defines frequency, power, modulation and other wireless condition of the link. The MAC defines the format of the data handling.

IEEE 802.15.4 support peer-to-peer network, a mesh network based on point to point can be built. Thus, IEEE 802.15.4 can be used to establish vehicular Adhoc

wireless network. Adhoc network are the autonomous system of mobile nodes which share a single wireless channel to communicate with each other. Vehicular Adhoc Network (VANET) improves road safety measure and may reduce traffic accident many of which are due to driver negligence or human error. In Vehicular adhoc network the driver is provided with necessary information such as warning signal from possible emergency situation ahead on highway.

Basic Features of Ieee 802.15.4

IEEE 802.15.4 standard is approved in 2003, as mention before it describes the physical (PHY) layer and medium access control layer (MAC) for Low Rate Wireless Personal Area Network (LR-PAN).

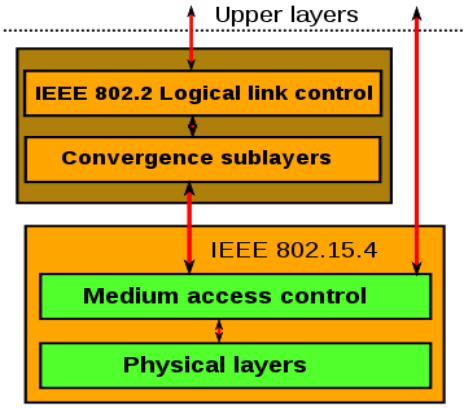

Figure 1: IEEE 802.15.4 Protocol Stack

The IEEE 802.15.4 use only the first two layers, the logical link control and the convergence sub layers of the OSI model as shown in figure 1. The standard also defines two types of network nodes such as Full Function Device (FFD) and Reduced Function Devices (RFD).The FFD serves as the coordinator of the personal area network and it is responsible for maintaining and monitoring the network and other devices. On the other hand RFDs can communicate only with FFDs of personal area network (PAN) and can never be coordinators.

A. The Physical layer (PHY)

The Physical layer (PHY) of IEEE 802.15.4 is responsible for the control of a radio transceiver. PHY maintains the transmission service as well as the interface to the physical layer management entity providing access to every layer management function and maintains a database of information on related personal area networks. The functions of PHY can be characterized as follows:

- Activation and deactivation of radio transceiver
- Energy detection within the current channel
- Link quality indication for received packets

- Clear channel assessment for Carrier Sense

Multiple Access Collision Avoidance (CSMA/CA)

- Channel frequency selection
- Data transmission and reception

IEEE802.15.4 PHY operates in three frequency bands with 27 radio channel. Details of the PHY operating frequencies and channels are representing as below:

Regions	Europe	America	Worldwide
Frequency band (MHz)	868 to 868.6	908 to 928	2400 to 2483.5
Communication channels	1	10	16
Channel bandwidth	600 kHz	2 MHz	5 MHz
Data transfer rate	20kbps	40kbps	250 kbps
Modulation	BPSK	BPSK	Q-QPSK

To access the radio channel, PHY uses Carrier Sense Multiple Access (CSMA) with Collision Avoidance (CA). The use of CSMA/CA ensures a successful transmission of data within a channel. Therefore, a multiple users or devices can access the same channel at different time without interfering each other. Although the IEEE 802.15.4 specifies three frequency bands the 2.4 GHz band is mostly used with Direct Sequence Spread Spectrum (DSSS) modulation to increase the bandwidth of the transmitted signal for efficient communication.

B. The Mac Layer

The IEEE 802.15.4 Mac Layer provides a service of enabling MAC frames transmission through the use of physical channel. The MAC sublayer manages all access to the physical radio channel and performs the following tasks:

- The MAC sublayer provides access to the upper layers through two Service Access Points (SAP)
- The MAC layer generates network beacons allowing devices to find an existing network
- It controls frame validation, manages superframes and controls channel access.

The IEEE 802.15.4 MAC layer specifies two operational modes:

- The non beacon-enabled mode and
- The beacon-enabled mode

In non beacon-enabled networks, devices use unslotted CSMA/CA channel access mechanism while in beacon-enabled networks devices use slotted CSMA/CA channel access mechanism.

C. Network Topologies

The IEEE 802.15.4 specifies two types of network topologies. The first one is peer-to-peer and the second one is star topology. Peer-to-peer networks are meant to serve as the basis for ad hoc networks capable of performing self-management and organization. In a star topology the coordinator of the network is the central node and

all communications between nodes pass through the central node. Whereas in peer-to-peer (P2P) network any device is allow to talk with one another directly. A typical P2P topology is shown in Figure 2. From a device role perspective, this topology also has one PAN coordinator that starts communication and the end devices. When joining the network, however, end devices do not have to establish their connection with the PAN coordinator. As to functional types, the PAN coordinator is an FFD and the end devices can be FFDs or RFDs. In this topology, however, end devices that are FFDs can have multiple connections. Each of the end device RFDs, however, can connect to only one FFD and cannot connect to another RFD.

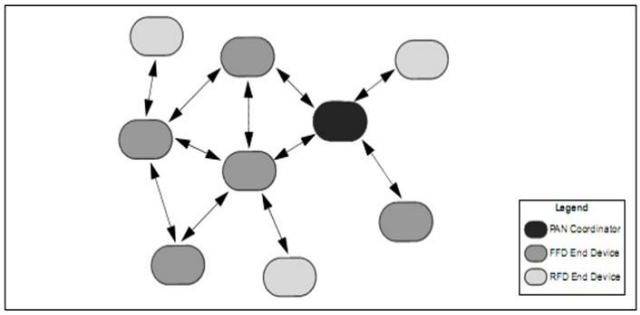

Figure 2: Peer-To-Peer Topology

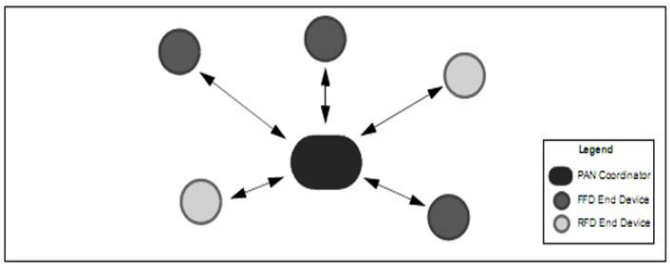

Figure 3: Star Topology

A typical star topology is shown in Figure 3. From a device role perspective, the topology has one Personal Area Network (PAN) coordinator that initiates communications and accepts connections from other devices. It has several end devices that join the communication. End devices can establish connections only with the PAN coordinator. As to functionality type, the star topology's PAN coordinator is a Full Function Device (FFD). An end device can be an FFD with its radios on all the time, or a Reduced Function Device (RFD) with its radio off when it is Idle. Regardless of its functional type, end devices can only talk to the PAN coordinator.

Vanet Using IEEE 802.15.4

Vehicular Adhoc Network (VANET) is automobile technology in which vehicles are allowed to communicate with each other. VANET includes vehicle-to-vehicle

communication and vehicle-to-roadside unit communication. There have been many design and proposed methodology in establishing VANET. Here we are using IEEE 802.15.4 networking protocols for setting up wireless vehicular adhoc network.

Figure 4: Vehicular Adhoc Network

In a VANET system, each vehicle is interlinking to one another as well as with the road side traffic units. The proposed system includes three units based on IEEE 802.15.4 wireless networking protocols to communicate among themselves. The first unit is control unit, and the second unit is monitoring unit, they are both equipped with touchscreen display and other sensors. The third unit is vehicle unit which have a compass, a graphics LCD and a warning buzzer.

The advantages of vehicular adhoc network can be summarized as follows:

- *Collision avoidance*: Vehicles approaching intersection point received a warning that another vehicle is approaching so as to avoid intersection collision.
- *Forward hazard warning*: An incident such as road accidents, slippery road, and traffic jam is collected by the vehicle and broadcast it to all other vehicle in its vicinity.
- *Speed limit warning*: vehicles travelling at a speed higher than traffic speed limits will get warning through the road side traffic unit.
- Traffic management: VANET system reduces traffic congestion by informing road condition to drivers and may divert the traffics to alternate route.

Any vehicle using VANET system can send and received information from one another and from the road side traffic units directly using peer-to-peer IEEE 802.15.4 connection topology.

Since IEEE 802.15.4 is a low power technology, it permits embedded system to operate over a long period of time. One of the important properties implemented in IEEE 802.15.4 is the channel energy scan. The energy scan indicate how much energy (activity/noise/interferences) there is in one (or several channels) prior to start using it. This way we can save energy choosing free channels when setting the network.

There are several reasons for using IEEE 802.15.4 standard in vehicular wireless adhoc network in areas where low data transmission rate is required and low power consumption is a major concern. IEEE 802.15.4 sensor networks can handle up to 64000 devices simultaneously. The beacon mode and non beacon mode are two types of communication mode process available in IEEE 802.15.4 for avoiding interference in an environment where several system are running on the same frequency band.

Here, we are using MiWi for establishing a wireless vehicular adhoc network. The MiWi P2P protocol is a variation of IEEE 802.15.4 and supports both peer-to-peer and star topologies. It has no routing mechanism, so the wireless communication coverage is defined by the radio range.

MiWi:

The MiWi P2P stack supports only non-beacon networks. In a non-beacon network, any device can transmit data at any time, as long as the energy level (noise) is below the predefined level. The MiWi P2P stack transmits and receives packets according to the IEEE 802.15.4 specification, with a few exceptions.

There are two ways to transmit a message: broadcast and unicast. Broadcast packets have all devices in the radio range as their destination. IEEE 802.15.4 defines a specific short address as the broadcast address, but has no definition for the long address. As a result, broadcasting is the only situation when the MiWi P2P stack uses a short address. There is no Acknowledgement for broadcasting messages.

Unicast transmissions have only one destination and use the long address as the destination address. The MiWi P2P stack requires Acknowledgement for all unicast messages. If the transmitting device has at least one device that turns off its radio when Idle, the transmitting device will save the message in RAM and wait for the sleeping device to wake-up and request the message. This kind of data transmitting is called indirect messaging. If the sleeping device fails to acquire the indirect message, it will expire and be discarded. Usually, the indirect message time-out needs to be longer than the pulling interval for the sleeping device.

In the MiWi P2P stack, only the messaged device will be notified by the radio. If the messaged device turns off its radio when Idle, it can only receive a message from the device to which it is connected. For the idling device with the turned off radio to receive the message, the device must send a data request command to its connection peer. Then, it will acquire the indirect message if there is one.

Conclusion

IEEE 802.15.4 wireless technology is a short-range communication system designed to provide applications with relaxed throughput and latency requirements in Wireless Personal Area Network (WPAN). The key features of 802.15.4 wireless technology are low complexity, low cost, low power consumption, low data rate transmissions, to be supported by cheap either fixed or moving devices. The main field of application of this technology is the implementation of WSNs. Due to the low data rate transmission and low power consumption it is well suited for using in Vehicular

Adhoc Networks. VANETs provide safety on road and minimize road accidents which are sometimes fatal.

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