IEEE 802.20 Based Broadband Railroad Digital Network – The Infrastructure for M-Commerce on the Train

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ABSTRACT

The broadband wireless access is emerging as a promising technology to meet the ever-increasing demand of M-commerce on the train. The traditional railroad communication system (RCS) is not only in charge of the traditional train scheduling, but also offers broadband WLAN services to passengers and provides the network platform to the intelligent railroad information system. This imposes a major challenge on the capability of the RCS in response to the increasing application requirements, particularly, the one for ubiquitous Internet access. To take the advantage of the rapid evolving mobile communication technology, this paper proposes an IEEE 802.20 based broadband railroad digital network, namely BRDN, for the next generation RCS. The paper further presents the scenario how BRDN operates and identifies the IP mobility as the major technical issue to be solved for BRDN. The predictability of mobile IP for the train-based applications will ease the difficulties in implementing BRDN. With the availability of IP standard for the next generation Internet - IPv6, BRDN will eventually become a reality.

Keywords: M-commerce; Broadband wireless network; Railroad Communication; Mobile IP

1. INTRODUCTION

With the advancement of information technology, M-commerce is undergoing a rapidly growth and exerting significant impacts on the economy. According to Finfacts' report based on several sources [8], the percentage of Internet users who use the wireless access grow from 16% in 2001 to 41.5% in 2004 (eMarketer, http://www.emarketer.com/). This figure will continue to get as high as 56.8% in 2007 with the total number Internet users almost tripled from that in 2001. In 2002, although only 2% of Internet users were using the "mobile cash" but 44% intended to use it later (ATKEARNEY, http://www.atkearney.com/). IDC (http://www.idc.com/) predicted that during 2001 to 2007, the M-commerce revenue in the US will grow from $127 million to $58.4 billion – more than 400 times.

Known as "wireless E-commerce", M-commerce generally refers to the use of wireless devices, such as mobile phones, to conduct electronic business transactions [17]. There are five value-added attributes of M-commerce to regular E-commerce [9][20]:

- Ubiquity: Available at any time and any location.
- Convenience: Convenient for users to operate.
- Instant Connectivity: Easily connect to the target.
- Personalization: Allows for preparation for personalized information.
- Location: Location-specific information and products.

As one of the most important scenarios of M-commerce, Internet access from trains has become an outstanding M-commerce issue among others. It is predicted that in the next five years, 625 million people will be traveling on Wi-Fi enabled trains around the world each year [3][5]. By 2008, train passengers will be spending 420 million dollars per year on in-transit wireless LAN hotspot services. Passengers in the train typically will stay a few hours to a few days in a small area that is like a mobile office more comfortable than staying in other moving vehicles. Thus, M-commerce allows passengers to conduct their business via the Internet. The key for the train-based M-commerce is the Internet access underpinned by mobile communications technology.

This paper is intended to propose the IEEE 802.20 based Broadband Railway Digital Network (BRDN), the wireless network infrastructure for the next generation railway communication system (RCS) based on the latest mobile broadband Internet access technology. The remaining part of this paper is organized as follows: Section 2 summarizes the status of RCS; Section 3 introduces the IEEE 802.20 standard; Section 4 presents a framework of BRDN based on IEEE 802.20; Section 5 discusses the key technical problems in implementing BRDN; finally, Section 6 concludes the paper.

2. THE EVOLUTION OF RAILROAD COMMUNICATION SYSTEM

The traditional railroad communication system plays an important role in train distributing and programming,

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and inter-section wireless communication. At the same time, it is responsible for the railroad application data transmissions, such as train serial numbering, wind pressure remote sensing and railroad alarm messaging. As the intelligent railroad information system is highly regarded as the future value-added service on RCS, the limited data transmission capability of the traditional RCS is apparently the bottleneck for an advanced railroad information system. As ubiquitous Internet access becomes the trend, RCS should not only support the operation management of the railway system, but should also offer the Internet services to support M-commerce on the train.

The evolution of RCS relies on the advancement of the mobile communication technology (MCT). Historically, each new generation of MCT has refueled the RCS with the revolutionary improvement. As illustrated in Figure 1, MCT has led RCS's evolution with each innovative generation (the thin line represents the history of MCT, and the bold line indicates the following development step of RCS).
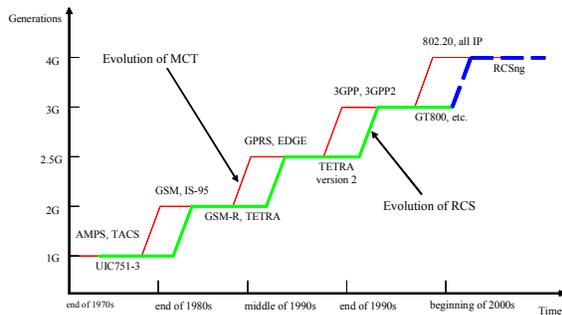

Figure 1. The development of MCT boosts the RCS's advance

In the last two decades, MCT has experienced rapid development, from the first generation (1G) to the third generation (3G) in technology, and achieved great commercial success. At the same time, RCS has evolved from analog communication system based on UIC751-3 protocol into the narrowband digital communication system based on 2G technology. The typical 2G technologies include GSM-R (UIC), iDEN (Motorola) and TETRA (ETSI), etc. The TETRA version 2 in planning by China's MoR possesses some 2.5G features [23]. Furthermore, the GT800 system developed by China's Huawei adopts the 3G technology (TD-SCDMA) and has been tested [10].

Now, the 4G technology based on IEEE 802.20 is rising on the horizon [2]. The basic idea of 4G is to merge the narrowband circuit-switching cellular phone technology with the broadband packet-switching technology. The IEEE 802.20 standard under discussion supports various vehicular mobility that classes up to 250 Km/h in a wide area network environment with spectral efficiencies, low latency, high transmission rate, and QoS. Its goal is

to enable worldwide deployment of affordable, ubiquitous, always-on and interoperable multi-vendor mobile broadband wireless access networks that meet the needs of business and residential end user markets. Although IEEE 802.20 demonstrates the promising future of mobile application, the narrow band digital mobile communication systems, such as GSM-R, TETRA, etc, are still the mostly available choice for RCS [7][21][24], only meeting the basic requirement for the operation of the railroad system. Even the 2.5G and 3G based RCSs, which are still under improvement, cannot satisfy the passengers' high demand for Internet access for M-commerce. This is mainly because it can only provide a peak bit rate up to 144Kbps when the mobile node is moving at a high speed. According to the status of RCS, it is a necessity to adopt the more advanced mobile communication technology.

3. IEEE 802.20 – THE KEY TECHNOLOGY FOR BRDN

Since July 1999, the IEEE 802.16 Working Group on Broadband Wireless Access (http://grouper.ieee.org/groups/802/16/) has been openly developing voluntary consensus standards for Wireless Metropolitan Area Networks with global applicability. Addressing the demand for broadband access to buildings, IEEE 802.16 provides solutions that are more economical than wired-line alternatives. The standards set the stage for a revolution in reliable, high-speed network access in the "last mile" of Internet by homes and enterprises [13]. On December 11th, 2002, the IEEE Standards Board approved the establishment of IEEE 802.20 Mobile Broadband Wireless Access (MBWA) Working Group (http://grouper.ieee.org/groups/802/20/). It described the scope of IEEE 802.20 as:

Specification of physical and medium access control layers of an air interface for interoperable mobile broadband wireless access systems, operating in licensed bands below 3.5 GHz, optimized for IP-data transport, with peak data rates per user in excess of 1 Mbps. It supports various vehicular mobility classes up to 250 Km/h in a MAN environment and targets spectral efficiencies, sustained user data rates and numbers of active users that are all significantly higher than achieved by existing mobile systems.

According to the above scope, the basic features of IEEE 802.20 include compatibility, coexistence, distinct identity, technology feasibility, and economic feasibility [11].

According to the MBWA announcement, IEEE 802.20 is aimed at mobile communication, and its data rate can reach more than 2Mbps in high speed mobile application. IEEE 802.20 is the first real broadband wireless network standard that dedicatedly supports the mobility of network. A comparison between IEEE 802.20 and others mobile techniques for traditional RCS are shown in Table 1 [10][12][13][23].

Table 1：IEEE 802.20 vs. Other Mobile Techniques used by Traditional RCS

Characteristics	GSM-R	TETRA version 2	GT800（3G）	IEEE 802.20
Data rate	2.4-28.8Kbps	96-384Kbps	2Mbps, < 144Kbps in high speed	16Mbps, > 2Mbps at the speed of 250mk/h
Latency	About 1000ms	About 500ms	About 250ms	About 30ms
Spectral efficiency	200KHz/8channel	25KHz/4channel	About 0.2b/s/Hz/cell	> 1b/s/Hz/cell
Cell radius	5~10 Km	10~15 Km	2~5 Km	> 15 Km
Spectrum	Licensed bands 876 -880/921-925MHz	Licensed bands 806 -821/851-866Mhz	Licensed bands below 2.7GHz	Licensed bands below 3.5GHz
Switching method	Circuit	Circuit	Circuit/Packet	Packet

4.   THE FRAMEWORK OF BRDN

In this section, we construct a framework for the BRDN underpinned by two wireless network standards - the IEEE 802.20 wireless WAN (WWAN) on ground and the IEEE 802.11x WLAN on train.

4.1   The Configuration

Figure 2 illustrates a configuration for a mobile network on the train implemented. A WLAN is deployed in a train with a typical configuration: The Ethernet (IEEE 802.3) cable is wired through all carriages via MVB (Multi Vehicle Bus); in each carriage, Wi-Fi access points are deployed with complete coverage of the area, and are hooked up to the Ethernet; end users access this WLAN via their mobile devices, such as notebook computer, PDA, mobile IP phone, etc. An IEEE 802.20 client interfaced to the Ethernet via a router connects the WLAN to the base stations of IEEE 802.20 on the ground, which jointly offer the transparent services on the physical layer and data link layer between the Internet and the mobiles nodes.

Because of the availability of NAT (Network Address Translate) technology, the whole network on train may only need a single IP address. A DHCP server can automatically assign each mobile node of the network on the train a dynamic IP address.
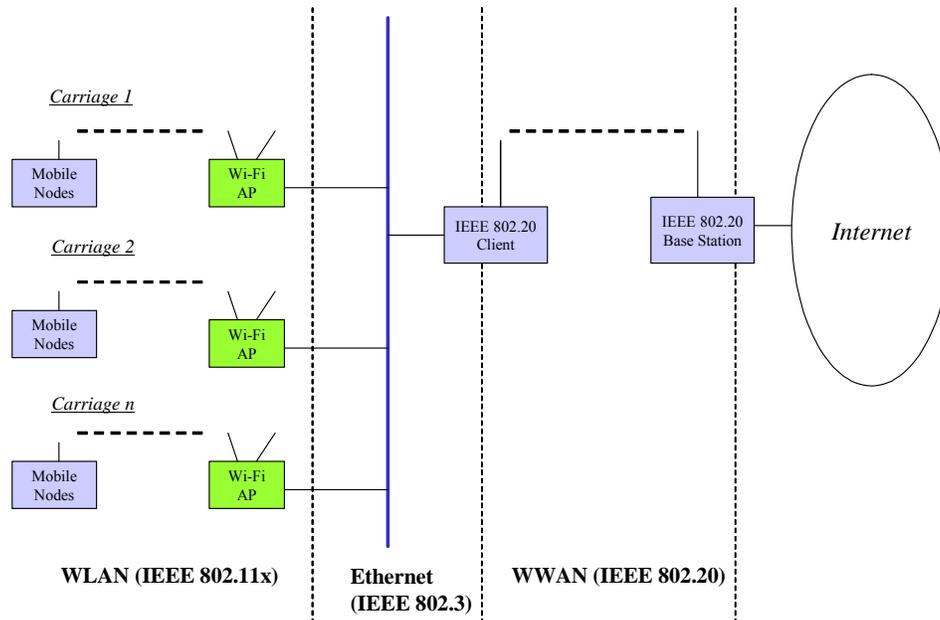

Figure 2. The Configuration of BRDN

The interconnection scheme of WWAN between the IEEE 802.20 base stations has several choices: IEEE 802.20, IEEE 802.16x, existing cellular communication systems infrastructure, and the cable, because these base stations are still. As we discussed in Section 3, IEEE 802.20 is supposed to be the best choice for its high-speed mobility support, with high data rate, spectral efficiency and low latency.

The train-based IEEE 802.20 mobile client as a whole is on moving when the train is in operation, switching from one network to another over time (about 10-30

minutes at the regular moving speed). Section 5 will discuss the mobile IP problem - how the train-based client remains reachable from the ground stations, while moving around in the Internet quickly, regardless of its current point of attachment to the Internet.

According the above configuration, the proposed BRDN will adopt IEEE 802.20 and 802.11x standards to implement the function of physical layer and data link layer. The physical layer provides the air interface of wireless network, and the data link layer offers reliable data frame transmissions between neighboring hosts, by use of the bit transmission function provided by physical layer.

4.2 The Operation Scenario

The working scenario of BRDN is shown in Figure 3. When a train departs from location A, the #1 base station provides the Internet connection to the train via #1's network. When the train approaches location B, it will contact both #1 base station and #2 base station at the border because there is a coverage overlapping between the two base stations. After the IEEE 802.20 client on train switches the connection from #1 base station to #2 base station, #2's network starts to provide the path to the Internet, and the network connection handover is complete. The network handovers happens in the same way when the train arrives at location C and location D.
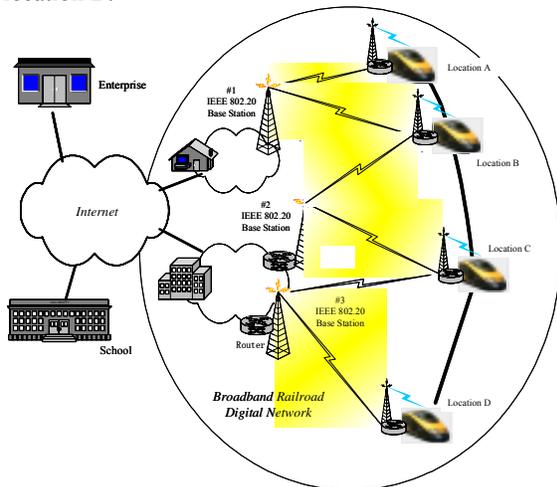

Figure 3. The operation scenario of BRDN

5. MOBILE IPV6 - THE KEY ISSUE IN BRDN IMPLEMENTATION

Broadband wireless network has generally raised a number of research issues aiming at the requirements from the mobile applications. Although many have proposed various resolutions for these issues, for example, mobile IP telephony, more effort has to be input to find the better ones that will eventually lead to commercialization. In the context of railroad based mobile applications, the same problems exist as in other

mobile IP applications, but there is a possibility that the problems in railroad based mobile applications can be solved by alternative approaches with better outcomes because of the specialty of the application environment. This section briefly covers two most outstanding topics: IP mobility in BRDN, and VoIP for BRDN.

Mobile IP introduced a solution of bi-address, with a long-term IP address on a home network (HN) and a "care-of address" (COA) when away from its home network. This home address (HA) is administered in the same way as a "permanent" IP address is provided to a stationary host. The COA is associated with the mobile node (MN) and reflects the mobile node's current point of attachment. Every time when MN handover to a foreign network, mobile IP requires it to bind its COA to Home Agent (HA) [14][15]. If MN is moved far away to HA, the latency caused by handover will be long, and will lose the packets sent to MN, and the network performance will decline seriously. This Seamless Handover question has attracted wide attentions. Many researchers have put forward their proposal [1][16][18][23]. Much of them are based on mobility detection, and some are based on mobility predictive. But, because of the complexity of mobile node's moving, both the mobility detection and predictive are hardly implemented.

The IEEE 802.20 mobile client on train is always on moving along with train, switched from one network to another at a fixed trajectory, particularly, the period of handover can be predicted by the train schedule [22]. Based on these premises, BRDN adopts a Predictive Pre-Handover (PPH) algorithm. PPH is based on the highly predictive of train's moving from one network to the neighboring network. Not only the arriving time, but also the ID and router's address of the next network are predictable. It adopts many effective methods such as actively mobility detecting, pre-registering and pre-transmitting and storage. The flow of PPH algorithm illustrated as below:

1) Initialization: Create the entry for each network handover and get the predictive handover table according to the train's schedule.
2) Handover predict: BRDN predicts the next network's ID, router's address and arrive time (t_p) according to the handover table.
3) BRDN creates the frequency of detection and detects the foreign network actively.
4) Pre-registering: BRDN implements the preparations for registering, such as authorization and authentication.
5) Pre-transmitting and storage: According to the result of step 3 and t_p, BRDN copies the communication data to the router of the network which about to handover.
6) BRDN triggers the handover process when it detected that the quality of the new network's signal is better than that of the former.

7) If there has any data missed, auto-transmit from the router's storage, and BRDN amends the predictive handover table according the result of this handover.

IPv6 is presently the IP standard for the next generation Internet, which can overcome the many known weaknesses of IPv4. With its 128 bits IP address IPv6 has realized the Stateless Address Auto-configuration (SAAC) [19]. Applied to the BRDN, IPv6 is able to configure each communication node on a train automatically with a unique global IP address freely. That implies that besides current IPv4 based dynamic IP assigning, IPv6 has the potential to provide a better solution. The operation for mobile IPv6 is shown in Figure 4.
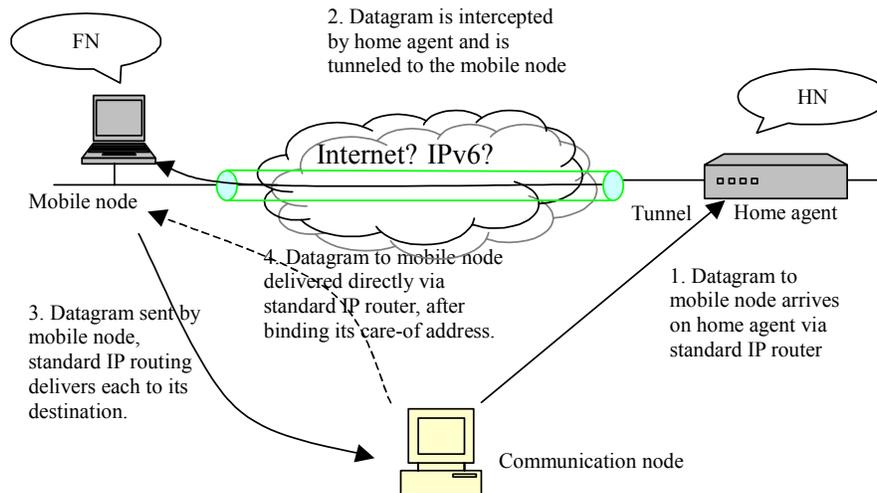

Figure 4. The operation of mobile IPv6

In a hybrid scheme, the WLAN on trains may still use mobile IPv4, which has been well explored recently, while the main connection to the Internet will be IPv6-based in order to support better IP mobility by taking the advantage of IPv6. A gateway between the WLAN and the IEEE 802.20 based WWAN will take care of the IP address translation.

Voice communication is a fundamental service demanded for RCS. In particularly, unless RBDN realizes the priority management, urgent call support, broadcast, multicast and quick establishment for call question, the RBDN based on IEEE802.20 can implement in rail-transit. VoIP application based on IEEE802.11x has been mature and deployed [4][6], which is the technology we introduced in the above sections.

5. SUMMARY

To extend M-commerce, the next generation RCS is a necessity for the advanced mobile network infrastructure. This paper presents current status of MCT and RCS, and introduces the latest mobile broadband wireless access technology IEEE 802.20. Although the standard of IEEE 802.20 is still under discussion and to be launched in 2005, its current specification has shown its promising potential in the near future in supporting the ubiquity of M-commerce. We further compared IEEE 802.20's technology advantage with other RCS solutions, and identified that constructing the BRDN based on IEEE 802.20 standard is not only feasible, but also urgent. This paper further brought forward a configuration for RBDN, with the considerations in the required features of next generation RCS and the technology advantages of IEEE 802.20. We also discussed the mobile IP problem for BRDN – the key issue in implementing the next generation RCS, covering the predictive mobility management for mobile IP and VoIP over RBDN.

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