Internet Access in Fast-Moving Trains based on IEEE 802.20 Technology

ABSTRACT

Advances in telecommunications technology have led to the development of novel wireless applications, one of which is IEEE 802.20 – a technology that emerged and brought with it numerous benefits such as internet connectivity in bullet trains. The train has been one location where it has essentially been difficult for passengers on board to enjoy high-speed internet connectivity. At that, the combination of high-bandwidth connectivity and fast-moving end-users (passengers in bullet trains) while maintaining service quality has been a major challenge in provision of broadband internet access in high-speed trains. Also, it is a challenge for railroad operators to keep railway information systems up to date, owing to fast-rising demand on high-speed transportation. As such, this paper discusses the necessity of the IEEE 802.20 criterion in bullet trains because of its high mobility rate, low latency and spectrum efficacy, and its application in railroad information systems.

Index Terms— broadband railway digital network (BRDN), bullet/high-speed trains, handoffs, IEEE 802.20, IEEE 802.16e/802.20, mobile broadband wireless access (MBWA), mobility.

1. INTRODUCTION

IEEE 802.20, also referred to as Mobile Broadband Wireless Access (MBWA), is a criterion that stipulates wireless broadband networks' technical features based on mobile internet protocol (IP) services; MBWA is meant to be a 4G mobile system specification. Its main goal is the development of a protocol for packet-switching wireless access enhanced for supporting service on the IP so as to facilitate the development of inexpensive and interoperable wireless mobile access networks that, by characteristic, will be "permanently connected." The focus of the IEEE 802.20 criterion is on genuine super-fast mobile broadband networks, with its interface aimed at increasing the rates of transmission data in real time across wireless MANs (metropolitan area networks) at greater-than-DSL (digital subscriber line) speeds. Such speeds will be attained via BSs (base stations) that extend to at least 15 km; mobile users are expected to benefit from the improved transmission speeds even while travelling at 155 mph speeds. At that, IEEE 802.20 is ideal for use in bullet trains.

In planes and trains, it was - until of late – practically impossible for travellers on board to have high-speed internet access. As regards trains, provision of internet access to rail users is sensible (from a business standpoint): passenger internet access would bring in more revenue for the owners of the train while bringing in more customers. Moreover, internet access in freight trains can provide real-time or near real-time cargo-related event tracking in-train, hence leading to a cutback in insurance costs to the train. Additionally, access to broadband internet in-train may also improve the train's safety since it will be possible for an operations centre to monitor carrier-related data in real time. It has become a significant objective for railroad operators in an increasingly competitive domain. Railroad transport is one of the transportation sectors with the highest demand for telecommunication services because of "the intrinsic mobile nature of the resources involved" [6, p. 430]. The railroad domain, however, presents rather distinctive and demanding requirements to broad-spectrum wireless transmission architecture, like reliability, high mobility, rigorous QoS (quality of service) markers, consistency with legacy/non-conventional applications, and high handover rate. The legacy applications are associated with train signalling & control systems. Communication availability is highly demanded by such systems; in the event that communication is lost, the signalling system gets disrupted, in turn stopping the train. The concerns thus are: (i) how the internet will be accessed by users aboard the train (from the access point); and (ii) how the train will be connected (thru the access point) to the internet. Railway signalling is one use for in-train broadband communication whereby the IEEE 802.20 can be deployed instead of the existing cable-based systems.

1. **SYSTEM DESCRIPTION**

The IEEE 802.20 criterion is particularly targets the physical (PHY) and medium access control (MAC) layers – the first and second layers of the open system interconnection (OSI) reference model [2]. The criterion has 2 modes of operation: the 625 kilohertz-spaced multicarrier (625k-MC) and Wideband. Both modes have their own separate and enhanced MAC and PHY layers. The 625 kilohertz-spaced multicarrier mode works with a carrier bandwidth of 625kHz and supports only (the) time division duplex (TDD) bandwidth – it supports aggregation of several carriers for only TDD. The Wideband mode, on the other hand, operates in all frequency division duplex (FDD) and TDD bandwidths [2] for uplink and downlink. IEEE 802.20 requires no device to support more than one mode, and terminal-access network interoperability is only guaranteed with each mode. Design-wise, 802.20 was intended to guarantee multi-vendor network equipment and terminal interoperability in every mode if the equipment is fully compliant with the message sequences, protocols and procedures identified in 802.20 for both modes. MBWA (as regards the wideband mode) is essentially made up of ATs (access terminals), network access (AN), and an AI (air interface).

The 802.20 criterion utilizes a layered design that is consistent with other IEEE 802 criterions, primarily comprising of implementation of PHY and MAC layers whereby at least 1 access terminal can communicate with an AP (access point) thru the air interface toward external networks. The 802.20 air interface should allow usage of IP-based high-speed services supporting usages that conform to current standards and protocols, like video, file uploads and downloads, streaming (video & audio), among others. Regarding mobility, 802.20's air interface supports speeds within a 35km/h-250km/h range; as per the speeds, a must-consider factor is spectral efficiencies within the acceptable range [2]. MBWA has the advantage of excellent mobility; of its main qualities, i.e. spectral efficiency, mobility, and low latency optimized for internet protocol services, MBWA's uniqueness owes to its *mobility*. For further emphasis, "IEEE 802.20 has specified that an MS could go to at most 250 km/hr" [1, p. 3], making (bullet) trains the best medium of harnessing 802.20 because of their supported travel speed.

III. STATE-OF-THE-ART

In [1], Abdulla and Shayan address the problem of mutual interference in their proposition of a solution that would utilize unique features of ultra wideband (UWB) and MBWA to stream in high definition. On one hand, UWB's bandwidth in a wireless personal area network is very large, and its best use is with high-definition video applications. MBWA, on the other hand, is a wireless metropolitan area network alternative optimized for wireless internet protocol in vehicles moving at high speed. As such, the authors "derive a generalized interference model for the MBWA system, which under specific conditions will yield … the maximum tolerated aggregate interference power" [1, p. 1]. The solution explained would wirelessly transmit high-definition video in high-speed train cars and would be MBWA-enabled because of MBWA's support for vehicular speeds of up to 250 km/hr.

Sarmiento, García and Parra [2] discuss the IEEE 802.20 criterion's suitability in high-speed trains, considering that its focus is "on true high-speed mobile broadband systems" [2, p. 1805] – in other words "increasing real-time transmission data rates in metropolitan area wireless networks at a speed greater than DSL (Digital Subscriber Line)" [2, p. 1805]. The authors also lay out the requirements for deployment (in high-speed trains, for example) that IEEE 802.20 must meet. Generally, the following are some of the requirements that railroad communication technologies must meet: -

1. *High Mobility and High-speed Vehicular Support.* Technologies for railway communications should support high vehicular speeds (up to 500 km/hr), thereby solving the problem of mobility, providing unbroken inter-cell handover with no loss of data and low latency.

2.*Low Latency.* Railroad information technologies should provide low end-to-end latency with the capability of supporting "high demanding real time applications in full mobility" [6, p. 432].

3. *Support for High Data Transmission Rates.* Rail information technologies should provide broadband data access in communication (uplink and downlink). The technologies should provide higher capacities (traffic volume per the number of end-users) than 2G and 3G technologies. As such, the design should provide support for the aforementioned related trend to enhance "the high quantity of data acquisition from train and wayside equipment and high capacity network utilization" [6, p. 432].

4. *End-to-end QoS.* Railroad information systems when utilizing packet or link-based technologies should provide QoS support, i.e. it should enable prioritization of essential applications. Priority access and emergency support constitute some of the main prerequisites for vital railroad services. Differentiated QoS levels should be possible via the deployed radio technology.

5. *Economical Deployment based on Accessible and Criterion-based technology*. Railroad information systems should enable economical deployment. For this to be possible, the technology deployed will be compliant with the international framework of standardization that further increases the suggested solution's economic viability. The architecture should facilitate interoperability of internet protocol equipment. PHY and MAC layers are the only layers that are covered by the criterions that outline the new wireless digital (data) transmission technologies. Identifying the layers alone is not enough to set up an interoperable broadband wireless network for railroads. Preferably, it is important to build "an interoperable network architecture framework capable to deal with the end-to-end service aspects such as QoS and mobility management" [6, p. 433].

Basically, [2] addresses the research gap regarding IEEE 802.20 owing to advances in telecommunications technology, and preference for IEEE 802.20 because of its support for "broadband wireless systems that allow high velocity, with vehicular speeds of up to 250 Km/h" [2, p. 1811]. The authors also briefly lay out the requirements that 802.20 must meet, which [6] expand further (though [6] generalizes the requirements, they essentially describe IEEE 802.20).

Zou, Jiang and Lin [3] proposed a BRDN (broadband railway digital network) based on IEEE 802.20 for the next-generation railroad communication system. Traditional train track communication systems offer broadband wireless LAN services to travellers and provide network platforms to intelligent rail information systems (RISs). However, since intelligent RISs are "the future value-added service …" [3, p. 772] on rail line communication systems, apparently the traditional rail communication systems' limited capability of data transmission was seen as the obstacle to an advanced RIS. Owing to ubiquitous access to the internet, rail communication systems should not only support rail management operations; they should also provide internet support services for in-train M-commerce. The suggested 802.20-based fourth-generation technology, owing to its high mobility support in a WAN "with spectral efficiencies, low latency, high transmission rate, and QoS" [3, p. 772], was considered to be the best existing alternative for an advanced RCS (rail communication system). The hindrance to its application in the RCS at the time was the deployment of limited-band digital mobile transmission systems like the Global System for Mobile Communications – Railway and TETRA (the most available RCS alternatives). They only met the key requisites for railway system operations.Even the RCSs based on 2.5G and 3G technologies that, by 2004, were *still* being developed, could not meet the travellers' high demand for access to reliable internet for M-commerce – primarily because they could "only provide a peak bit rate up to 144Kbps when the mobile node is moving at a high speed" [3, p. 772].

The proposed BDRN in [3] is interoperable (supported on the ground by IEEE 802.20 wireless WAN and IEEE 802.11x wireless LAN in-train). In the bullet train, a wireless LAN is implemented with a standard setup: all the cars are wired with an Ethernet cable (802.3 standard) thru multi-vehicle bus. In every car, Wi-Fi APs with total area coverage are fixed and then connected to the Ethernet. In-train passengers access the wireless LAN thru their smartphones, PDAs, notebooks and laptops. An 802.20 client linked to the Ethernet thru a router hooks up the wireless LAN to on-ground IEEE 802.20 base stations that "jointly offer the transparent services on the physical layer and data link layer between the Internet and the mobile nodes" [3, p. 773]. Internet connectivity for the passengers is enabled thru an 802.16e/802.20 gateway that is in the train's first (the locomotive) and last carriages.

Authors in [4] explore a number of methodologies for provision of broadband internet access to bullet trains. The report seeks to fill the existing gap in in-train internet access, since a definite means of connecting moving trains to the internet is yet to be developed. Of the numerous difficulties presented, *handoffs* are of particular interest. The authors refer to the proposition in [5], i.e. IEEE 802.20 technology that was then under development, to ensure smooth handoffs. 802.20 is preferred because of the insufficiency of 3G mobile networks in providing high data transfer rates able to support many end-users in a bullet train. As per [4], for smooth handoffs to be possible between BSs, the train should make two MBWA connections. The access terminal(s) in the train will be connected to 2 different BSs in the access network. The bullet train, however, "would maintain a single IP address, using Mobile IP, throughout its journey" [4, p. 21]. Moreover, given that the train's arrival and departure times are known, instances of handoffs should be managed via a PPH (predictive pre-handover) system that will pre-set the appropriate routes following a handoff. The train's access node(s) will "actively monitor the received signal strength from IEEE 802.20 stations …" [4, p. 21]; the node will prompt a handoff every time the strength of the signal received from the new BS exceeds the strength of its current BS.

In [5], the authors of [3] address the problem of out-dated RISs; they explain the necessity of updating the existing RISs owing to the fast-rising demand on high-speed transportation and competition from other means of transport. The authors delve into the BRDN as the new-generation rail information system technology via discussing its key elements: “the Wireless Vehicle Network (WVN) in each vehicle, the Wireless Train Network (WTN), the Train-Ground Internetworking (TGI), and the infrastructure of BDRN along the railway track” [5, p. 1]. The focus here is on the BRDN *infrastructure/backbone* and TGI elements. Deployment of in-train internet (*intranet*) will require OPS (an on-board proxy server) to serve as an entry between the internet and the in-train intranet. The authors suggest 2 on-board proxy servers with 802.16e/802.20 clients mounted in the first and last cars to enable mobile IP handoff when the train moves from network to network. The authors explain the functioning of the BDRN: along the train track, 802.16d BSs are installed “with the provision of broadband wireless access for the non-mobile equipment, which connect to the 802.16e/802.20 base station directly” [5, p. 4]. Interoperability between 802.16d and 802.16e/802.20 is also discussed. Both broadband wireless technologies pack potential; improved 802.16e supports speeds of up to 200 km/hr with a data transmission rate of 30Mbps, whereas MBWA supports speeds of up to 250 km/hr with 16Mbps data rates. Additionally, both technologies are appropriate for metropolitan wireless access within a fifteen kilometre radius. Evidently, IEEE 802.16e/802.20 technologies meet broadband TGI requirements for high-speed trains.

1. CONCLUSION

Transport via train is one of the sectors in the transportation industry whose demand for telecommunications services is huge, because of the in-built nature of the components/equipment involved. The railway domain, however, presents rather distinctive and demanding requirements to broad-spectrum wireless transmission architecture, like reliability, high mobility, rigorous QoS (quality of service) markers, consistency with legacy/non-conventional applications, and high handover rate. These requirements are met by the IEEE 802.20 criterion. IEEE 802.20 was developed as a system intended to furnish in-motion users (e.g. passengers in high-speed trains) with access to all kinds of information at enhanced rates of transmission. Interoperability with other wireless systems of internet access is one of MBWA’s advantages. Furthermore, its key features include spectral efficiency, mobility, and IP service-optimized low latency. Mobility of IEEE 802.20 is what makes it unique; it supports vehicular mobility speeds of up to 250 km/hr in WANs with spectral efficacies, high rates of transmission and low latency. That is what makes 802.20 a justifiable alternative for utilization in bullet trains. MBWA is also the choice technology for rail information systems when combined with 802.16e, as discussed earlier.

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