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Mobile Hotspot in Railway System

Abstract

With the ever–growing need for mobile high–speed access, there is an apparent demand to extend access towards mass transportation vehicles such as trains. In this paper, we propose a novel networking paradigm for railway system. The architecture realizes spatial diversity, and transparency to mobile devices. We further investigate the link layer design approach of the architecture, with the use of erasure coding. The concept of information raining is explained, with simulations illustrating system throughput cyclicity due to positioning of vehicle.

I. Introduction

In recent years, the Hotspot technology has gained tremendous popularity with the demand of mobile Internet access. In public areas such as airports, bus terminals and train stations, travellers may use their laptops and handheld devices to access the Internet while waiting for their departure. As more locations are becoming Hotspots, there is an apparent demand to extend high–speed Internet access towards mass transportation vehicles such as long–haul trains and metropolitan subways. In these vehicles, passengers are often idle and bored in a confined space. Organizations that enable mobile Hotspots in their mass transportation systems offer much appreciated convenience to their customers, and may ultimately experience an increase in ridership.

It is challenging to facilitate Internet access using traditional wireless local area network (WLAN) technology. The naive approach would be to place numerous access points (AP) along the transportation route to provide coverage to mobile users. However, this setup is highly unscalable with typical APs that cover small radii of 50m to 200m. This is especially true with long–haul railways where hundreds of kilometers of coverage is required. Whenever a vehicle travels across AP boundaries, WLAN must perform handoff operations to large number of users. For instance, a vehicle travelling at 72km/h demands handoff every 10s with AP coverage of 100m radius. These frequent handoffs must be performed without significant delay and packet loss, yet these handoff rates are infeasible with the current Mobile IP architecture.

Likewise, the cellular wireless industry thrusts towards enabling high data–rate services with 3G cellular networks. The challenges with cellular systems are similar to WLANs. For instance, there is an issue with cellular planning. Terrain obstacles such as hills, buildings and tunnels may cause shadowing and large delay spread of several microseconds to certain sections of these routes, which impair transmission quality in terms of bit–error–rate (BER) and achievable bandwidth. These factors justify the use of microcells along the transportation route, however these microcells result in frequent handoffs due to high mobility, and may generate interference to existing macrocells in the vicinity.

In this paper, we propose a novel system architecture to facilitate mobile Hotspots that is applicable to both WLAN and cellular systems. This is coherent with the recent development in the convergence of these two technologies. We then consider design issues when implementing our architecture at link layer, followed by simulation results. For the rest of this paper, we shall illustrate our discussion on downlink traffic forwarding due to the emergence of asymmetric data applications in mobile devices.

II. System architecture

All handheld devices possess critical constraints in hardware component size, computation power and battery power. Consequently, they can only process relatively simple procedures, and only one small antenna can be installed in most devices. Conversely, one common feature among trains is their large physical size. More powerful networking equipment can be installed inside vehicles without practical space and battery power limitations. It is also ideal to install multiple antennas around the vehicles, connecting them to the networking equipment.

Furthermore, unlike generic mobile users, trains have a network of defined paths to travel. By installing repeaters at close vicinity along the network of paths, line–of–sight (LOS) can be guaranteed between repeaters and vehicles that move along the network.

We propose a system architecture for providing mobile Hotspot in railway system. The system diagram is shown in Figure 1. Similar to backbone networks and mobile switching centers of cellular systems, the mass transportation system communications network is a cloud of networking equipment that is responsible for routing traffic between the Internet and local information distribution centers we refer to as *zone controllers* (ZC). Zone controllers are responsible for traffic dissemination within their local region, such as a railway section of several kilometers. They are also responsible for detecting the presence of vehicles and their mobile users. Stationary repeaters are positioned along the responsible path. Repeaters and ZC may be connected via fiber cables, or via daisy chaining of wireless links with intermediate repeaters. These repeaters then relay traffic of ZC to multiple antennas that are installed on top of moving vehicles. Inside each vehicle locates a *vehicle station* (VS) that gathers traffic from vehicle antennas, and relays them to internal repeaters. The internal repeaters may be access points or cellular repeaters that provide service to mobile users, if the concerned technology is WLAN or cellular system respectively. Thus, passengers enjoy seamless mobile Hotspot service with no adjustment at the mobile terminal.

Fig. 1. Proposed architecture for mobile high-speed access in railway system

Repeaters may be placed on the ground near the railroads, with antennas on top of trains shifted to the side to allow line–of–sight, or in the case of underground subway systems, repeaters may be placed at the top of the tunnel. In any case, the paradigm is applicable to both urban and rural environments.

The separation distances among repeaters, between repeaters and antennas, and among antennas on the vehicles depend on many factors such as the type of antennas employed and their transmission range. We foresee separation distances in most systems do not exceed 100m, and may be as few as several meters.

V. Conclusions

In this paper, we have investigated a novel system architecture that enables high–speed access in mass transportation vehicles. Spatial diversity is achieved through the installation of repeaters and vehicle antennas. The architecture is transparent to mobile users in the vehicle. We further investigate the link layer design approach of the architecture. The concept of information raining is also described, and simulated to illustrate cyclicity phenomenon.

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