Using Bandwidth-Road Maps for Improving Vehicular Internet Access

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I. INTRODUCTION

Thanks to the developments in the Wireless Wide Area Networking (WWAN) technology, e.g. the 3G, HSDPA, and WiMax, daily commuters now can access to the high-speed mobile data services from a fast-moving vehicle. However, in the vehicular environment, where users continuously change their geographic locations, the WWAN bandwidth fluctuates significantly, due to heterogenous wireless radio and network load conditions at different locations. This bandwidth instability presents formidable challenges to engineer a stable wireless access to the Internet. To guarantee a smooth connectivity, the underlying communication substrate will have to constantly adapt to the changing networking conditions.

Despite the complex causes behind the wireless bandwidth instability, empirical studies [1], [2] of wide area wireless networks have revealed that wireless bandwidth is a function of geographical location. Given this strong correlation, we propose to map WWAN bandwidth to the existing road network through repetitive measurements. These bandwidth-road maps could provide information such as “if you are near the intersection of Street X and Street Y, you can expect an average bandwidth of 1.2Mbps from network provider A”. By using such bandwidth-road maps and the digital road maps available from the on-board navigation unit, an on-board communication system in a vehicle can potentially achieve a faster adaptation to impending bandwidth fluctuation during a given trip. In this poster, we show that the traffic scheduler in a multi-homed vehicular network can use the bandwidth estimates from such maps to intelligently schedule multiple traffic flows among multiple service providers’ networks during a vehicular trip. Our results show that our principle can significantly improve the quality of experience of on-board audio sessions.

II. BANDWIDTH-ROAD MAPS

To create a concrete example of bandwidth-road maps, we have developed a simple apparatus using off-the-shelf hardware and in-house developed software as illustrated in Fig. 1. To account for network and technology diversities, we measure three different WWAN networks (two different HSDPA networks and one pre-WiMax standard iBurst network). Our system measures the downlink bandwidth along the route, using a lightweight packet-train based client-server program [2], which was simultaneously run over each WWAN link. The client tags the collected samples with the location coordinates and time, and sends them to the server.

We assume a location granularity of 500m, wherein each 500m section corresponds to a location segment along the route. For each location in bandwidth-road maps, we store the average bandwidth, which is computed as the exponential weighted moving average (EWMA). The average value is continuously updated on the fly whenever a new measurement is available. We conducted 75 repeated measurement trips along two non-overlapped typical daily commute routes (7Km and 13.5Km) in Sydney metropolitan area. From the collected traces, we are able to create bandwidth-road maps for each WWAN provider and route. Fig. 1 shows the map for one of the routes for a specific HSDPA provider.

III. APPLYING BANDWIDTH-ROAD MAPS IN MULTI-HOMED VEHICULAR NETWORKS

In multi-homed on-board networks (see Fig. 2), the Mobile Router (MR) and Home Agent (HA) run the NEMO basic protocol and seamlessly connect on-board user devices to the
Since the effect of using the bandwidth-road maps can significantly improve the perceived quality of an audio, we refer to such an event as a glitch. Clearly, reducing glitches can significantly improve the perceived quality of an audio session. Since the effect of using the bandwidth-road maps is most pronounced in the short instance after a change in the vehicle’s location, we present results that compare the performance of the two schemes in the first 25m following each location change. Fig. 3(a) compares the total number of glitches observed from all active flows. BW-MAP reduces the number of glitches by 45% as compared to React. Note that, after entering into a new location, React still uses the estimated bandwidth from the previous location in making a scheduling decision. This leads to incorrect flow assignment and overloading some of the links, as the actual bandwidth at the current location can be very different from that from the previous location. The sessions assigned to the overloaded links inevitably suffer packet loss and hence result in poor audio quality. On the other hand, as the mean bandwidth values used in BW-MAP is close to the actual bandwidth at the new location, BW-MAP achieves better performance. Fig. 3(b) shows that BW-MAP reduces the number of flows suffering glitches by 35% in comparison with React. Fig. 4 plots the total number of glitches encountered at different locations along the route. It is evident that, at some locations, e.g., #4 and #8, BW-MAP significantly reduces the glitches by more than two-fold.

Fig. 2. Interfacing bandwidth-road maps with a multi-homed scheduler

Fig. 3. Average results comparison

Fig. 4. Total # of glitches at different locations

IV. CONCLUSION

In this poster, we have demonstrated a principle to capture the strong correlation of location and WWAN network bandwidth in the form of bandwidth-road maps. We demonstrated how these maps can be used to intelligently schedule traffic in a multi-homed mobile network. Our preliminary results show that our approach can effectively improve the user experience of on-board audio streaming.

REFERENCES