MobiCom 2009 Poster: Accelerometer-Assisted Power Efficient Wi-Fi Networking on Public Transportation System

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Using mobile devices to access the network service over public transportation system provides ubiquitous network access. Accelerometer has become standard equipment in mobile handheld devices. We proposed a power saving mechanism, AAPS, which integrates accelerometer and Wi-Fi devices to facilitate opportunistic communication while conserving power. In the scenario of BS in the station and MS on the vehicle, MS would idle during the inter-station period and waste a lot of energy. AAPS enables the devices to detect the vibration caused by moving vehicle and stay in sleep mode until the vehicle approaches next station. When MS is approaching or in the stations, accelerometer will trigger the WLAN to connect to BS in the stations. We implemented AAPS and conducted practical experiments on Taipei MRT. The experimental results showed that AAPS can save MS energy consumption without degrading the throughput performance.

I. Introduction

Nowadays, the wireless internet service for the passengers on public transportation systems becomes urgently important. As a result, some researches discuss the delay-tolerant network on the bus systems [1] [2]. In the scenario of public transportation system with Wi-Fi internet service as in Figure 1, the BS locates in the station and MS moves with vehicle. The MS can only interact with BS when the vehicle is in or near the station, but the connection would break in the inter-station period. We can improve the transmission efficiency in the station by some mechanisms [3] [4], and provide uninterrupted service with larger buffer. However, there's no internet service during the inter-station period, so the MS should enter sleep mode during that period for the energy-efficient concern. Here is the subsequent problem: How can MS know when it should sleep or wake? Opportunistic communication is considered as an effective solution for DTN-like vehicular networking environment [5]. We are inspired by the opportunistic communication paradigm to exploit the transmission opportunities occurred when vehicle is stopped in the station or moving slowly approaching stations or exiting stations.

Recently, accelerometer is equipped in many handheld devices such as mobile phones and PDAs. Accelerometers can detect the acceleration in three dimensions, and the power consumption of it is very low (usually lower than 1mW). In contrast, the power consumption of wireless card is higher: it consumes 1000mW-1400mW when working and 830mW when idling; fortunately, it consumes only 130mW in sleep mode. Therefore, we can save a significant amount of energy by using a mechanism assisted by accelerometer to determine when it should wake or sleep according to the environmental changes. We proposed an accelerometer-assisted power saving mechanism (AAPS) to provide this problem a simple solution.

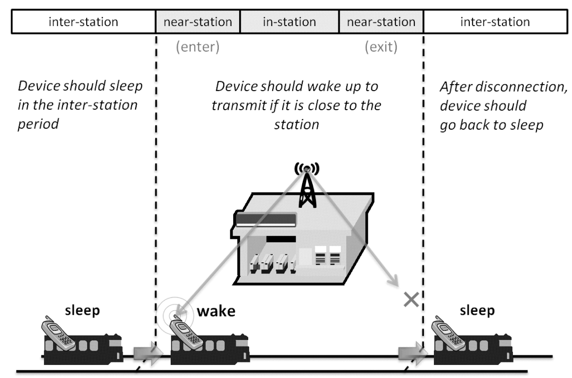

Figure 1: The scenario of Wi-Fi network over the public transportation system

II. Accelerometer-Assisted Power Saving Mechanism

The environment of public transportation system can be divided into three phases according to the position of the vehicle: in-station phase, inter-station phase and near-station phase. Consider this scenario described in Figure 1. In the in-station phase, the vehicle is totally static, and the MS can receive the best quality of service from BS; in the inter-station phase, the vehicle keeps moving with high speed, and the MS is out of the covering range of BS; in the near-station phase, the vehicle moves with low speed, and the MS can hear the signal from the BS. While the vehicle is moving, it will vibrate randomly because the road or rail is not completely smooth; the higher the speed, the stronger the random vibration.

If the mobile device can detect what the current phase is according to the level of vibration by its accelerometer, it can know whether it should wake to listen or not. Given a public transportation system, we can set up a specific threshold of vibrating force to tell the inter-station phase from the other two phases. When the vibrating force is above the threshold, then we keep the MS in sleep mode. If it is below the threshold, the MS can find out that it is in the in-station or near-station phase, and MS should turn on its wireless interface to hear the beacon from BS. If MS cannot hear BS, it should go back to sleep mode. Once the connection between MS and BS is built up, it should not disconnect until the vehicle leaves the station. After the vehicle leaves the station, the MS will disconnect from BS and enter the sleep mode automatically. The vibrating force will keep the device from waking up until the vehicle slow down in order to enter the next station. Consequently, AAPS can turn on the wireless interface only when the vehicle is near the station or in the station and reduce the energy consumption significantly. AAPS can be implemented not only on mobile devices but also on other kinds of wireless communication on vehicles. For example, if we set the BS on the traffic lights or bus stops, the video recorded by the monitor on bus can be uploaded when it stops near these infrastructures. And in this scenario, AAPS also can provide a good power saving solution.

III. Implementation of AAPS

To implement AAPS, we have to understand the user behavior. While the users using the mobile device, they may hold the mobile devices in arbitrary direction. Consequently, the designed mechanism must analyze the output of accelerometer regardless of the direction of the device.

We can map the 3-D output of accelerometer to a vector in the 3-D space. When the device is static, the gravity vector $\vec{G}$ points at somewhere in the 3-D space. When the vehicle is vibrating, it will add as a random weight to the vector as $\vec{G} + \vec{n}$ and cause the vector to "vibrate" in the 3-D space. Now we define the instantaneous vibrating weight (IVW) as $|\vec{G} + \vec{n}| - |\vec{G}|$. IVW can reflect the degree of vibration at a specific moment regardless of the direction of the device. Moreover, we define a weighting function w[t] to weight the new data higher than the old ones. Now we weight the square of IVW with w[t] in past n seconds and define $K = \sum_{t=0}^{n} w\left[t\right] IVW^2 \left[t\right]$.

Then, we compare K to a threshold Th. When the MS is in the sleep mode, if $K > Th$, we keep the MS sleep; if $K < Th$, MS will be triggered and wake up to listen. If MS cannot hear any massage from BS when it wakes up, it turns back to sleep mode until next trigger. Otherwise, the MS and BS will build up the connection until the vehicle enters the next inter-station phase. Even though the users may vibrate the device in the in-station or near-station phase, the MS will never go back to sleep until it receives no signal.

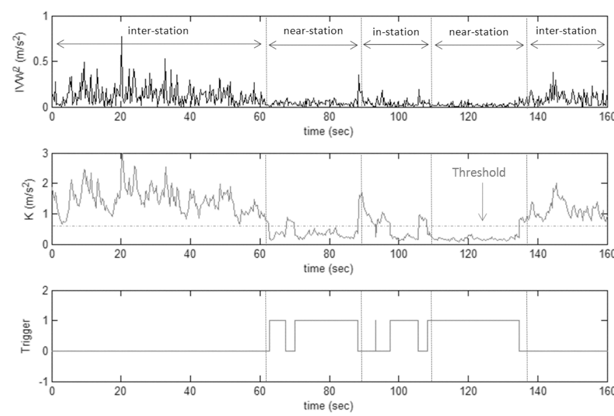

Figure 2: The relations between IVW, K and Trigger.

Figure 2 shows part of our experiment. The vibration caused by vehicle can be described by the IVW^2, and K changes according to the IVW^2. If K is below the threshold (the red dotted line), the trigger rises. We can see that the trigger rose only in the near-station and in-station phase due to less vibration, and the fallen triggers in these periods were resulted from the user's hand vibration. MS woke up from sleep mode when the trigger was rising. In this figure, the MS woke at 63 seconds until it left the covering rage of BS. Consequently, now we have implemented the AAPS in our system, and it can function correctly in the environment of public transportation system.

IV. Performance of AAPS

We took our experiments on Taipei MRT System. We use the ASUS EeePC 900 as our BS and MS, and the MS is connected to Hitachi H48C 3-axis accelerometer. The MS and BS use Wi-Fi and work in ad-hoc mode. The BS sent 30Mbps-CBR traffic to MS. On

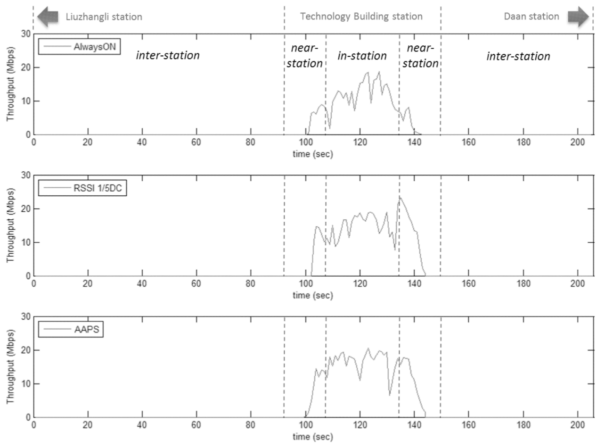

Figure 3: The throughput of three groups versus time when the vehicle passed through the Technology Building station.

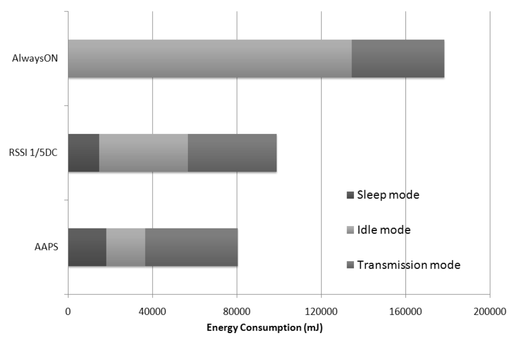

Figure 4: The energy consumption for three schemes.

average, AAPS can keep the MS in sleep mode in 96%-99.5% of the time in inter-station phase and save about 80%-90% of the energy during that period.

The following is part of our experiments on the Mucha line of Taipei MRT system. The MS was on the vehicle and moved from Liuzhangli, stopped at Technology Building station for a while and moved toward the Daan station. In this experiment, we included other two experimental groups in comparison with AAPS group: One is the ”AlwaysON” group, which keeps the wireless activated all the time. Another is ”RSSI 1/5DC” group, in which MS wake from sleep mode periodically with 1/5 duty cycle to listen to beacons from the BS. If the RSSI of signal from the BS is lower than certain level, the MS will go back to sleep mode. This is one of the common mechanisms used for saving the energy. The three groups are tested under the same conditions in the experiment.

In Figure 3, we can see that AAPS group and AlwaysON group start the transmission almost at the same time, which shows that AAPS can wake the device and start the transmission with negligible delay. The slightly difference in throughput was result from the difference between machines.

Generally, the power consumption of accelerometer is extremely low (lower than 1 mW), so we can take only the power of wireless interface into consideration when calculating energy consumption. Figure 4 is the energy consumption for the 206-second time period in Figure 3. Overall, AAPS consumed 45.1% of the energy consumed by AlwaysON and 81.3% of it consumed by RSSI 1/5DC. In the inter-station period, AAPS consume only 15.6% of the energy consume by AlwaysON and 52.5% of the energy consume by RSSI 1/5DC. AAPS can help MS to sleep in the whole inter-station, so the longer the inter-station period, the more energy AAPS can save. AAPS is shown to be a practical power saving mechanism in the environment of public transportation system.

V. Conclusion

We developed AAPS, an efficient power saving mechanism for communication in public transportation environment by the aid of accelerometers. By sensing vibration caused by vehicles, AAPS can switches on Wi-Fi to connect to in-station access points. The experiments on Taipei MRT system show that AAPS is power-efficient without degrading the performance of throughput. We are in the progress to applying AAPS to other types of vehicular environment and improve the performance of wireless networks.

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