Bluetooth Content Distribution Stations on Public Transit

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1. INTRODUCTION

In this poster, we introduce our Bluespots project, in which a small computer on a bus serves as a BCD station in a university public transit scenario.

An important feature of the application space that we envision is that it depends only on single hops between devices. The primary form of communication will be between user mobile devices and Bluespots, or information waypoints. In later incarnations of this system, larger-scale dissemination can be achieved by using application-level peer-to-peer connections. However, we do not think of the system as a general data transit system. We consider it more as an implementation of social networking, in which users only participate in functions that are in line with their own interests and goals.

1.1 Related Work

This work was motivated primarily the Haggle project from Intel Research, Cambridge and the University of Cambridge [5]. The goal of the Haggle project is to allow local device connectivity to play just an important role in data transit as an alternative to infrastructure-based networking.

The sort of research done under the umbrella of the Haggle project also falls, in a broader context, under the area of *delay-tolerant networking* (DTN) [1]. Many related projects can be found at the DTN website.

The UMassDieselNet project [7] is in the process of creating a testbed for DTN environments, using public transit buses. These testbeds are for general purpose DTN experiments, including routing and content distribution. However, the system only supports WiFi connectivity.

The Mechanical Back-haul [4] and Berkeley TIER project [6] use public transit vehicles to move information from kiosks in remote villages to dense city centers with higher bandwidth communications. These projects differ in that they are using vehicles for data transit, rather than the final hop of content distribution.

Jetcheva et al propose a multi-tier system using city buses, to provide Internet access in a city, using ad-hoc routing technologies [3]. Our work differs in that we are not trying to provide standard Internet services, but rather, a targeted set of services that are more appropriate for the public transit environment.

The Yet Another Access Point (YAAP) project [2] from Intel Research, Cambridge, presents a device that a user areas around as a wireless agent that acts on behalf of the user in the background.

MobiShare'06, September 25, 2006, Los Angeles, California, USA.

2. DESIGN RATIONALE

2.1 Motivating Applications

In this section, we will present some examples application to motivate the deployment of a public-transportation based BCD station system.

The first example is based on the popular digital music downloading services, like iTunes. Such a music subscription service can provide short music samples that are available on bus BCD stations via a Bluetooth connection to a cell phone or PDA. Riders can sample the newest and latest music as they travel to their destination. In a more thorough setup, in which individual users can securely authenticate themselves with the bus BCD stations, users can place orders for songs via their cell phone. The BCD station will collect orders, and upon arriving at a central location, like a bus stop, or the bus depot, the orders can be processed in a batch.

The BCD station might also be used to serve news headlines to users, using a newsfeed format such as RSS. Buses can fetch all the news headlines from various providers like CNN or Slashdot. Then, users can browse a list of available feeds on the bus, and choose those of interest, and fetch the information via Bluetooth.

2.2 System Description

The goal of the Bluespots system is to provide 'man-in-the-middle' approach to data access for users on public transportation systems. The system will allow riders on the public transportation system to take advantage of normally idle 'transit time' to access information that might be of use to them. In order to achieve this, BCD stations are placed on public transit vehicles. These stations receive and synchronize data when they are in WiFi range (for example, at a major station), and serve out data at all other times. The BCD stations can serve data using standard TCP/IP service over WiFi, or can serve data using a specialized Bluetooth application for mobile devices that only have Bluetooth support.

The central pieces of the bus Bluespot system are the stations that are placed on all of the buses in the public transit system of interest. These stations serve as the waypoint for data flowing in and out of the system. Figure 1 gives a high-level view of the architecture of one of the BCD station devices. The station consists of an isolated version of a number of potential services, like web, SMTP, and FTP. These services are provided via TCP/IP over a WiFi link, or can be accessed via Bluetooth. The services provide cached data that is local to the device. The cached data is obtained via the WiFi interface when the bus is near a gateway (e.g., at a depot). The BCD station serves as a combination of a DTN proxy server, and a content distribution network (CDN) node.

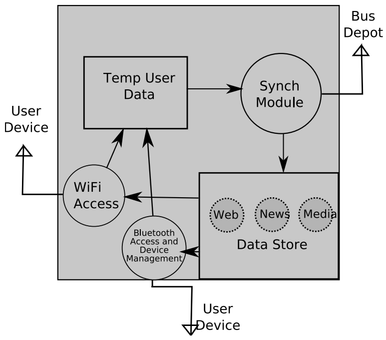


Figure 1: Architectural Overview of a Bluespot

- **Data Store** - Here, the public data that users can access will be stored. This will be items like web pages, news headlines, or media clips.
- **User Data Store** - The user data store stores information associate with users that have connected to the system. For example, preferences, or messages.
- **Synchronization Module** - This module manages receiving data from the Internet and caching it locally.
- **WiFi Server Module** - This module handles user connections from WiFi-based mobile devices.
- **Bluetooth Server Module** - This module handles user connections from Bluetooth-based mobile devices.
- **Device Management Module** - This module manages Bluetooth accessibility for various available Bluetooth-based mobile devices.

3. EXPERIMENT

3.1 Experimental Setup

In order to evaluate the connectivity environment in a real public transit-centric network, we collected real-world data using small wireless sensor nodes that contain a Bluetooth radio. The devices are Intel iMotes, which contain an ARM core as well as a Bluetooth radio stack.

The motes run a simple Bluetooth inquiry program. Every 2 minutes, the device does an inquiry for 5 seconds. All devices detected during this inquiry period are noted. These experiments give a list of contacts—with start and end times—that a particular mote has during its lifetime.

4. RESULTS AND DISCUSSION

As we analyze our collected data, we focus on how the results motivate a BCD station-based approach, as opposed to the multi-hop pocket-switched networking scenario.

Table 1: Basic Experiment Statistics

	Bus #1	**Bus #2**
Motes Deployed	35	33
Length of Experiment	110 hrs	110 hrs
Number of Devices Seen	461	586
Number of Contacts	11796	11742

The numbers in table 1 give us a rough estimate of how busy a Bluetooth-based BCD station system would be in the *current* Bluetooth environment. Of course, not all of these users would be using the system every time they board the bus. At the same time, there are a number of devices that were missed because Bluetooth was disabled. Though not perfect, this data gives us an estimate of the potential number of BCD users.

We note that there is a slightly higher number of devices detected in the second experiment. This supports the hypothesis that there are a number of Bluetooth-capable devices that have the Bluetooth radio disabled, but that they would be willing to enable it to receive some services.

For all of the subsequent results and discussion, there was no discernible qualitative difference between the first bus experiment and the second bus experiment. So, all of the following analysis is based on the data from the **Bus #2** experiment, since slightly more devices were seen, overall.

4.1 Contact Duration

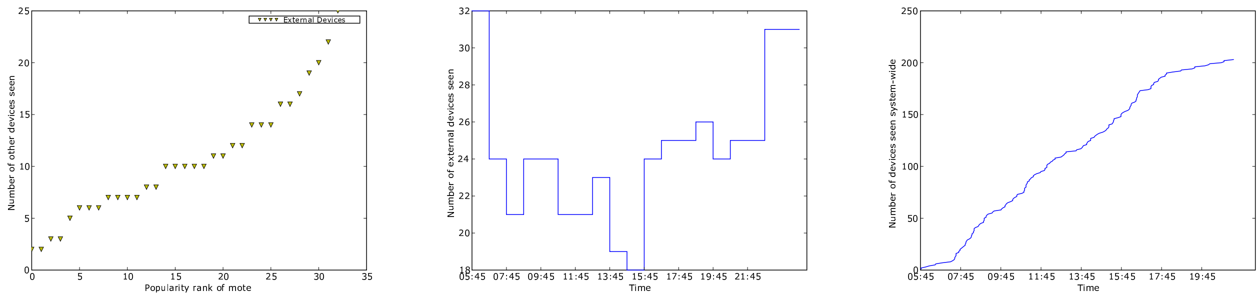
Next we examine the contact durations of the mote. Contact duration times can give us insight about how long of a period of time motes will have to take advantage of connectivity. This sort of information is useful as it can give us a better idea of the scale of information that can be exchanged with pocket switched networks. For example, we'd like to know whether we only have time to exchange short text messages, or perhaps larger photos, or even further, large audio/video files. Figure 3 shows us the CCDF of connectivity durations for the first bus experiment.

Contact duration times will help us to decide how to tailor the applications so that the user can get the most benefit from them. If all the service offers is the downloading of large amounts of information, or huge media files, but the contact times are often to short to finish a transfer, then the system is useless.

We can see in the CCDF that a large portion of the contacts (75%) are 2 minutes or less. This amount of transfer time, with the typical Bluetooth 1.1 transfer speeds of 30kbps (the typical speed the author experiences during a Bluetooth transfer), mean that there will be enough time to transfer 1-2 Megabytes of data during a typical contact. So, the BCD station service will be suitable for song samples, or textual data and images, but larger video files or large programs would not be a suitable content option.

4.2 Network Coverage

The graph in Figure 2 shows how many unique Bluetooth devices one iMote sees directly. Again, the graph shows the total numbers of Bluetooth devices that were in range of a



(a) # of devices seen by each mote (b) # of devices per hour (c) # of devices reached system-wide

Figure 2: Reachability

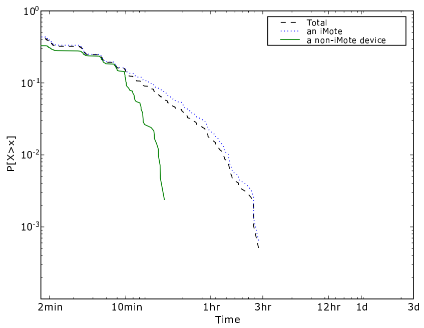


Figure 3: CCDF of contact duration times

particular mote, over a 16 hour period (one service day). This graph shows us that during a typical day, a bus might see anywhere from 3 to 30 distinct users.

In Figure 2(b), we see how many devices are seen throughout the entire bus system, per hour. Over the course of the day, we see anywhere from 18-32 external devices per hour. These are most likely conservative estimates, given that there are likely to be a number of mobile devices that still have Bluetooth disabled. Figure 2(c) shows us a different point of view. In this figure, we see how many devices could potentially have been served as time progresses. There is a steady increase in the number of devices met, as the day progresses, and through the course of the day, about 200 devices are served in total.

5. CONCLUSION AND FUTURE WORK

In this paper, we have outlined the design of a public-transit based content distribution system that is accessible via Bluetooth connectivity. The system will use delay-tolerant networking operation and multiple interfaces to provide data to public transit riders so that they can make opportunistic use of travel time to retrieve information or send messages.

Furthermore, we show preliminary experimental results that motivate the deployment of such a system. these results are just the tip of the iceberg. The data collected is only from the point of view of 30-40 nodes, so many external connections are missed. Regardless, these experiments allow us to find patterns in the way people connect, and as more and more similar experiments occur, the picture will become more complete.

The data we have shows us that a BCD station-based content distribution system is a feasible idea, as there are already a significant number of people with Bluetooth-capable devices.

6. ACKNOWLEDGMENTS

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