DTN-enabled Infostation and Cinema-in-a-Backpack

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ABSTRACT

Delay Tolerant Networks (DTNs) aim to enable content distribution in areas where little to no access to affordable communication channels is available. We are interested in DTNs for reaching out into under-served regions in growing economies, when distributing media and videos from cities to rural areas. DTNs enable content distribution in such areas, using mobility of devices and avoiding the need for traditional network infrastructure. The content is distributed to the target destinations using buses equipped with *infostations*, namely wireless DTN-enabled devices. Mobile cinema entertainment, possibly combined with educational content, will be the use case. Micro-entrepreneurs in remote villages will be provided with low-complex small *cinema-in-a-backpack* systems, which allow them to screen the content and start with a micro-business activity around the show events. In this paper, we present our wireless infostation and the cinema-in-a-back that we have built for the purpose and ready for a six-month long field deployment in rural South Africa, in partnership with local institutions.

Categories and Subject Descriptors

C.3 [**Special-Purpose and Application-based Systems**]; C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Wireless communication*

General Terms

Design, Experimentation

Keywords

Delay Tolerant Networking; Mobile Cinema; Wireless Networks

1. INTRODUCTION

Hundreds of millions of people living in rural areas still lack network coverage. The International Telecommunications Union (ITU) estimates that only 31% of the developing world's population can access the Internet [1] and that 95% of people in East Africa currently without network coverage are in rural areas without grid power [2]. The number of mobile users continues to grow impacting the fundamental economics of people's lives [3] and their communications with friends and family [4]. This impact is particularly large in rural areas of developing countries. By analysing patterns of expenditure on mobile phone services at the Bottom of the Pyramid (BoP), Agüero et al. [5] found that communication services are necessities among the poor.

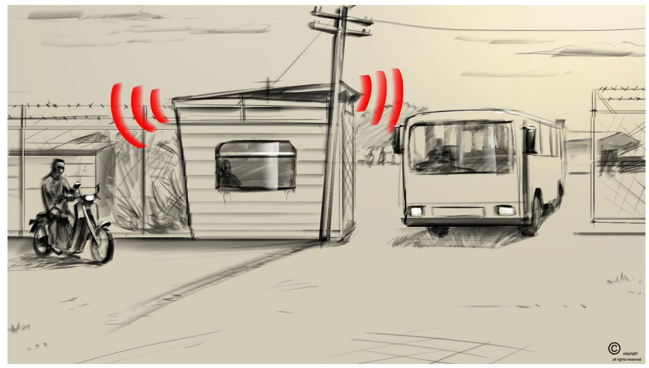

Figure 1: A Bus forwarding data to a micro-entrepreneur through a fixed infostation placed in a bus station in rural South Africa.

DTNs [6] offer a viable low-cost alternative to cellular wireless communication networks in areas that are underserved. We want to reach out to these regions with a low-cost approach for media distribution. For that, we are developing and testing a network system driven by DTN wireless devices. In such networks, mobile infostations (see Figure 2 (right)) mounted on public buses deliver content without the support of telecom operators or any other network infrastructures (see Figure 1). Such devices communicate only with their direct neighbors using local WiFi radio communication. DTNs provide flexible multi-hop connectivity by leveraging intermittent contacts among mobile radio devices. Delay tolerant networking employs the store-carry-forward paradigm where data is stored locally by mobile devices, carried while moving and forwarded when coming within the transmission range of another device. DTN nodes may send packets of arbitrary size, also termed bundles. A bundle is the protocol data unit of the DTN bundle protocol. The bundle protocol provides support for partial bundle

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transfer when communication links may not last long enough to complete the data transfer. Such a functionality enables communication over short contact durations so as to avoid wasting link capacity with incomplete transmissions [7].

In our use case, micro-entrepreneurs equipped with low-complexity cinema-in-a-backpack systems (see Figure 2 (left)) can screen educational and entertainment content in remote villages. We present our work in a six-month ongoing project that provides communities in rural South Africa with cinema experience by training micro-entrepreneurs in the operation of a DTN-enabled micro-franchise. In this paper, which follows from our previous work [8, 9], we provide a general overview of the DTN scenario in Section 2. In the Section 3 and 4, we present the DTN-enabled infostation and the cinema-in-a-backpack device, respectively. A brief summary of related work is provided in section 5. Finally, Section 6 concludes the paper.

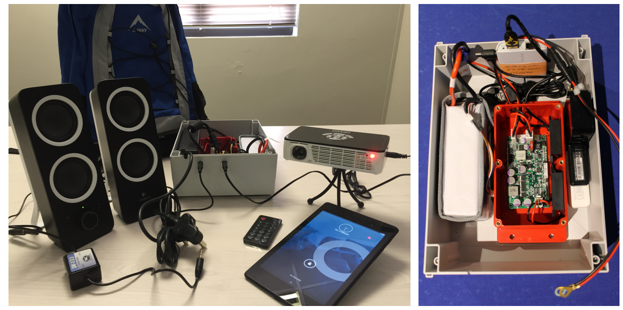

Figure 2: Cinema-in-a-backpack (left) and mobile infostation (right).

2. DTN SCENARIO

Multimedia content will be delivered with the help of DTN-enabled mobile infostations. Infostations are battery-powered Wireless Local Area Network (WLAN)-enabled devices mounted in buses and bus depots. Infostations act as peers that broadcast the content. The multimedia contents are archived at the fixed infostation located at the main bus depot in the city of Pretoria, which is within a 3G/LTE covered area. Every day, such a fixed infostation fetches a list of contents requested by the micro-entrepreneurs from a server located in the Internet cloud (micro-entrepreneurs are provided with a catalog of the available contents which can order by sending an SMS to the server), finds such requests in the local archive, and injects them in the DTN network. From this point, data are sent throughout the DTN network once infostations are in radio range. The mobile infostations serve as intermediate relays (data mules), which carry the content between the server and final destination, which in our case, is a fixed infostation installed in a bus depot located in a rural area. We have identified three bus depots, Siyabuswa, Vlaklaagte, or Kwaggafontein, about 135Km north-east of Pretoria, which serve several rural communities. Multiple micro-entrepreneurs have access to the DTN and may obtain different media at the same time. Once micro-entrepreneurs are in the proximity of the fixed infostation, they can download the content by means of their WLAN-enabled mobile cinema devices (see Figure 1).

Audio watermarking [10, 11] is used to detect copyright infringements. For this purpose, we have designed and implemented a software application able to capture location-based audio watermarks embedded in the soundtrack of the movies. Watermarks can contain, for example, information related to the location where the projection takes place, e.g. GPS coordinates.

3. DTN-ENABLED INFOSTATION

Infostations are wireless weatherproof boxes, each of which contains a WiFi router equipped with external memory storage, battery supply, GPS receiver, 3G dongle and a mini-UPS (see Figure 3 (right)). We have selected the TP-Link TLMR3040 Ver. 2.0 WiFi router for the infostations. Since the memory of the router is not sufficient for our purposes, we connect a USB hub to the router and use it to accommodate external memory storage. In addition, the GPS receiver and the 3G dongle are also attached to the hub.

The GPS receiver is used to track mobility of the infostations. The 3G dongle allows the fixed infostation in Pretoria to fetch the list of requests of the micro-entrepreneurs from the server on a daily basis. Besides, it allows each infostation to send useful information, system and network performance metrics and mobility traces (GPS coordinates) whenever cellular network is available. This provides some monitoring of the system and enables us to detect failures. All of the infostations have sufficient memory to store all the data sent by the source. The mobile infostations have been designed to be powered up by three different sources: the vehicle battery, the supplementary internal lithium-ion polymer battery, or the power grid. Such power sources are connected to a mini-UPS (Uninterruptible Power Supply) which provides instantaneous protection from input power interruptions by supplying energy stored in the supplementaty battery. The mini-UPS can handle a maximum and minimum input operating voltage of 30V and 6V respectively, and an input current limit of 10Amps. The actual upper bound load current of the system is 4Amps. We added two 12V/5V converters to connect the router and the USB hub to the mini-UPS. An AC/DC converter (INPUT: 100-240VAC, OUTPUT: 12V 5Amps) is also provided to connect the mobile infostations to the power grid.

The infostations have been configured with an OpenWrt release [12], an embedded operating system based on the Linux kernel, and the IBR-DTN, a C++ implementation of the Bundle Protocol (rfc5050) [13] designed for embedded systems [14], [15]. IBR-DTN provides different routing schemes and supports the TCP and UDP convergence layers.

4. DTN-ENABLED CINEMA-IN-A-BACKPACK

Mobile cinema entertainment, possibly combined with educational content, will be the use case. Micro-entrepreneurs will be provided with a low-complex, small cinema-in-a-backpack system, which consists of the following components: a tablet, a pico-projector, speakers, and an extra-battery (see Figure 3 (left)). They can download the multimedia content from the DTN network and screen it in remote villages by means of the tablet. An AC/DC converter and a supplementary lithium-ion polymer battery (22.2V 6200mAh) are connected to a mini-UPS and packed in a weatherproof box. The actual upper bound load current of the system is 4.5Amps. Such a box powers up both the pico-project and the speakers, whose power cables have been modified to be plugged in. Because of the common power source, a ground loop isolator has been used to filter the noise and to improve sound quality.

5. RELATED WORK

Wireless networks exploiting public transport systems have been attracting attention in recent years. Initial work focusing on rural environments in developing regions where buses connect a number of villages spread over a large area is conducted by [16–18]. Their common goal is to provide network access for delay tolerant applications such as e-mail and non-real time web browsing. DakNet [16] uses computers with a disk and Wi-Fi radio attached to buses on a bus route between villages. E-mails and other data are downloaded from the village and uploaded to the Internet or to other villages along the bus route. On the same bus network, a system of throwboxes [19, 20] was deployed to enhance the capacity of the DTN. KioskNet [21] is also a network of rural Internet kiosks that provide data services in remote regions. Vehicles with on-board computers ferry the data between the kiosks and gateways connected to the Internet. In [22–24], campus bus networks designed to serve students and faculties who commute between colleges or from/to nearby towns are proposed. In these settings opportunistic networks are usually characterized by a relatively small number of nodes when compared to a fully edged urban environment.

Bus networks in urban environments are usually characterized by many contact opportunities and frequent contacts [25–28]. In [25] the authors propose a commercial application based on a multi-tier wireless ad-hoc network called Ad Hoc City. It provides Internet access by means of access points responsible for a geographical area. Using the same real data set, [26] propose a cluster-based multi-copy routing algorithm for intracity message delivery. Here nodes are clustered based on their encounter frequency. To reduce the overhead effect of multiple copies, [27] propose an optimal stopping rule when forwarding. In [28] the public transport system of Shanghai is used to test the performance of a single-copy probabilistic forwarding mechanism. A recent work about performance analysis for deployment at urban scale is presented in [28]. In this work, the authors analyzed inter-contact times of the Zurich and Amsterdam transport systems discovering that they follow an exponential distribution. Based on their ndings, they are able to predict the performance of the epidemic routing protocol using a Markov chain model.

6. CONCLUSION

In this paper, we present our DTN-enabled infostation and cinema-in-a-backpack in an ongoing project that aims to provide communities in rural South Africa with cinema experience. We introduce the use case scenario and show the devices we have built, both hardware and software components, to distribute digital content with a low-cost delivery mechanism and screen it in remote villages. We envision DTN networks that are locally operated by community members, built with existing low-cost hardware and software components, and sustainable, with profit rolled to benefit the community.

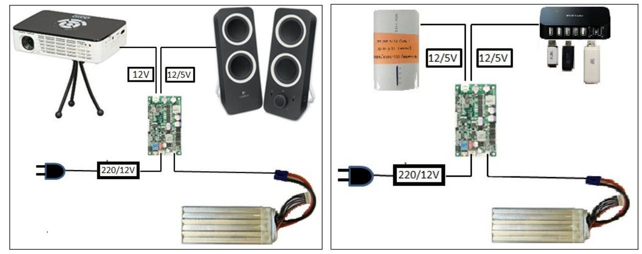

Figure 3: Diagram of the cinema-in-a-backpack (left) and mobile infostation (right).

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