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contributing a short news. So, the fourth issue of the AHSN TC Newsletter features one high quality news item gently provided by Dr. Luis Henrique M. K. Costa (UFRJ), Dr. Igor M. Moraes (UFF), and Dr. Miguel Elias M. Campista (UFRJ and LIP6). We thank them as well as all the previous contributors for their effort to make this newsletter successful towards fulfilling its objectives.

PREFACE

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The IEEE ComSoc Ad Hoc and Sensor Networks Technical Committee (AHSN TC) aims at sponsoring scientific and technical activities facilitating the dissemination of knowledge in the areas of ad hoc, sensor and mesh networks. In an attempt to make all the TC members as well as the AHSN worldwide community aware of what is going on within our main areas of concerns, this newsletter had been set up*. The newsletter aims at inviting the authors of successful research projects and experts from all around the world with large vision about AHSN-related research activities to share their experience and knowledge by

**The AHSN TC Newsletter has been started in 2008, and then re-started in 2012 after 2 years of a stop due to the sad and tragic loss of our friend and colleague Professor Mieso Denko, from the University of Guelph (Canada), who was one of the initiator and an active leader of this Newsletter. In his memory the newsletter had been re-started in 2012 as a tribute to his life's work in research, education and services to the networking community as a whole.*

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IEEE ComSoc AHSN TC Newsletter

News about Vehicular Ad Hoc Networks Research and Implementation in Brazil

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Abstract- Ubiquitous network access and mobility evolved from research subjects to development projects thanks to the growth of new wireless communications technologies. Particularly in Brazil, we are developing a prototype, called ReBUS, to provide network services in vehicular environments. Our goal is to provide basic network services inside the buses that are often used by the academic community on university campi. By using portable devices equipped with IEEE 802.11 wireless interfaces, users are able to send messages and receive informative files from the university. We have developed a hybrid network architecture that combines ad hoc and DTN forwarding techniques enabling certain applications to be used during connectionless periods. Currently, we are installing the network infrastructure at the UFRJ campus and developing specific applications to this scenario.

I. Introduction

Currently, more and more users are willing to be online “anywhere and anytime” as a consequence of the increasing popularization of mobile networking along with the growing communication capacity of mobile devices. This phenomenon has been often called ubiquitous networking and is already impacting on worldwide economy. Statistical inferences estimate that, until 2013, 900 million users around the world will be connected to the Internet via mobile devices, and part of them would even carry a mobile device during vacation to be fulltime connected to their office [1]. The higher Internet dependency pushes the creation of online services, offered to users while they are working at home and also while they are walking on urban areas and moving on streets by car, bus or train, among other mass transportation alternatives.

Considering the *in voga* communication technologies, wireless networking is, by far, the one which better suits the ubiquity requirement. These networks, besides reducing wiring infrastructure, they are in broadcast by nature which facilitates user mobility

support. Such characteristics make wireless networking an attractive option at the viewpoint of implementation simplicity as well as economical impact. In spite of all the physical propagation issues, the popularization of wireless networking is notable. Therefore, many investments from the electronic industry have been made and a huge number of new products are launched daily on such competitive market. Although all this success, the Internet mobility support does not experience the same developing progress. The mobility support problem has attracted many research efforts, but many of them are not applied in practice, especially if considering the low cost requirement.

Among all sorts of mobile networks, the vehicular scenario is probably the one which faces the most severe impact of lack of connectivity. Hence, vehicular ad hoc networks (VANETs) are receiving special attention because they represent an important landmark toward ubiquity. The considerable dynamics of such networks may result in frequent link breakages and rapidly quality of service loss during vehicular movement. VANETs can be considered a special case of mobile ad hoc networks, where most network nodes are mobile and a few fixed access points are used to guarantee connectivity. In VANETs, the network participating nodes are vehicles equipped with embedded wireless interfaces, users carrying wireless devices inside vehicles, or static access points along roads or streets. The concept of VANETs is wide and includes the vehicle-to-vehicle case, the communication between vehicles and the static infrastructure, e.g. routers positioned atop road side units, and the communication within vehicles, which can be composed of several sensors, for instance. In this letter, we focus on last implementation experiences in Brazil, which aims at providing Internet access even if intermittent to vehicles via road side static infrastructure. Among some applications developed for this specific scenario are message exchange content dissemination, and transit information.

II. Brazilian Scenario

Brazil is a continental country with several different socio-economic characteristics. Therefore, connecting the entire country even by wired infrastructure was only possible at the late 90ies with a huge investment from the Brazilian government, starting from the privatization of the telecommunication sector and the creation of regulatory institutions to supervise the expansion of the network and, consequently, of the telecommunication service to all Brazilian people. At that time, cabling the whole country was already a challenge because of the huge rural and forest areas, which count on very few or none infrastructure, or poor urban areas disorderly occupied.

Today, the reality is changing, and most the Brazilian people have mobile phones. Some of them can even have 3G capable devices. Nevertheless, the inherited social-economical problems persist, although in a lower degree, but still affect users so as to quickly dive into this new interconnected era. For the moment, the wireless technology which would allow users to have Internet access in a ubiquitous fashion is the 3G. This technology, however, is not yet available everywhere. Besides, all the costs involved for the users are still prohibitive for most Brazilians. Hence, in this scenario, another alternative is of utmost importance toward the ubiquitous communication service.

As a first solution, we have to consider low cost and minimum communication service guarantees. By doing that, we could promote the participation of users with limited income, leading to the popularization of the communication infrastructure. Thinking again in the Brazilian dimensions, this is still a hard task. Therefore, to fire up the network, we consider delays and also the collaboration of users with more powerful wireless devices, i.e. smartphones, laptops, and tablets. These two requirements are

seen in cooperative network, which is the case of the mobile ad hoc networks with delay tolerant capabilities, equipped with IEEE 802.11 wireless interface cards.

III. Vehicular Network: Hybrid Solution

The combination of vehicular networks and delay tolerant networks (DTN) can suits well the Brazilian requirement as mentioned earlier. In this section, we first briefly describe both networks and, at the end, we introduce the resulting hybrid network.

III.1 Vehicular Networks

Typically, there are three main architectures of vehicular networks, as illustrated in Figure 1: pure ad hoc, infrastructure, and a combination of both [2]. The infrastructure architecture (V2I – Vehicle-to-Infrastructure), which are adopted in our implementation, employs static nodes installed along the roads. These static nodes operate as IEEE 802.11 access points. They centralize all the network traffic, acting as a communication relay. The key advantage of the infrastructure mode is the higher connectivity and straightforward Internet access. Currently some works refer to vehicular networks as VANETs, even when there is infrastructure.

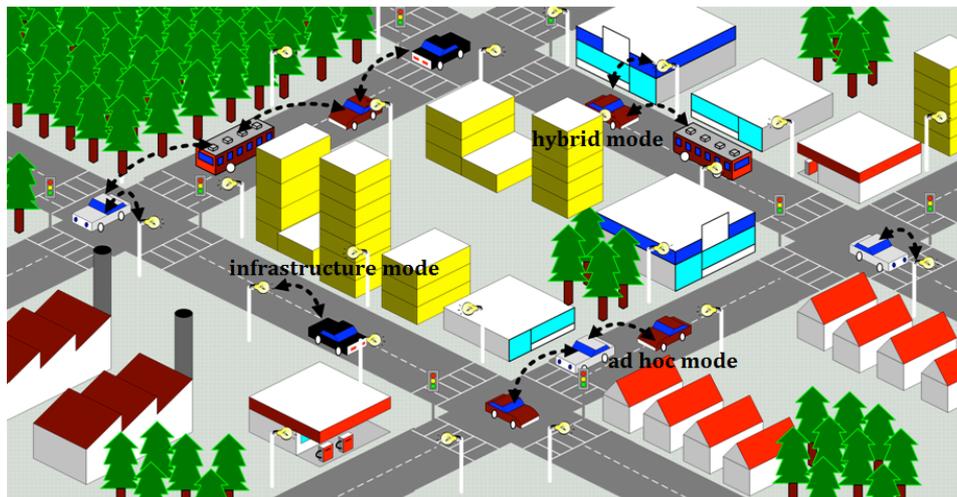


Figure 1: Vehicular networks architecture.

The communication among vehicles shows important challenges, such as high mobility and contact time between pair of nodes, which may be not enough to start a connection and, furthermore, to transfer data. The feasibility of IEEE 802.11 networks were already investigated in previous experiments to check whether these networks can be used in such environment. Conducting outdoor experiments in UFRJ (Universidade Federal do Rio de Janeiro) campus and using off-the-shelf equipment, it was possible to evaluate a baseline performance of vehicular networking. From those experiments, we could extract configuration parameters and possible improvements to be taken into account by communication protocols used for data transfers in vehicular networks.

III.2 Delay Tolerant Networks

The main characteristics of delay tolerant networks are: long and variable delays, and frequent disconnections. To minimize such issues, DTNs use, besides persistent storage, the message switching technique. In message switching, no circuits are previously established between source and destination. Hence, nodes do not execute any phase

before sending data. When a message needs to be sent, it is (persistently-) stored and forwarded node by node, from source to destination. Consequently, the destination not necessarily needs to be active at the time the source node has sent the packet because the relay nodes can store the message and deliver it later, in an upcoming opportunity.

Although it is possible to implement the message switching technique at the application layer, making all relay nodes to behave as application gateways, it would be required to develop all application taking into account the problem of long delays and disconnections. Moreover, for the sake of interoperability between conventional networks and DTNs it is important that the specificities are located above the transport layer. Based on these characteristics, the IRTF (Internet Research Task Force) has adopted the utilization of an overlay on top of TCP/IP and below the application layer, called the bundle layer [3].

III.3 Hybrid Networks

One important shortcoming of vehicular networking is the connectivity requirement. Therefore, the network cannot operate as it is if there is not a certain amount of nodes. This problem can be referred as an adoption problem, which means that the network must have a minimum number of nodes to be always guarantee connectivity. In a first moment, the adoption may be gradual and not sufficient to meet users' performance expectation. Even in the presence of static points, it will not be possible to guarantee permanent network connectivity. As a consequence, vehicles participating of the network at this initial phase may have to deal with service interruptions and frequent disconnections. These problems are similar to the ones faced by delay tolerant networks, which because of the scarce number of network nodes, do not guarantee the existence of end-to-end paths between source-destination pairs. This is the reason why the hybrid solution, vehicular networks and DTN, fulfill our initial goal which is to offer to users a basic networking service even in periods of network disconnection.

IV. The ReBUS Approach

The goal the ReBUS project (<http://www.gta.ufrj.br/gt-rebus>) is to develop a system prototype that allows users inside buses to access basic network services even during connectionless periods. We are using the buses that serve the academic community in UFRJ campus to conduct our experiments.

IV.1 ReBUS Network Infrastructure

In our prototype, we have four main components: client nodes, mobile nodes, road side units (RSUs), and the proxy server. To access the network, users must have a device equipped with an IEEE 802.11 wireless interface card. These users are called clients of the hybrid network and are able to run an open source operating system which provides support to the implementation of the DTN protocol stack. The smartphone used was a Nokia N900 running Linux Maemo [4] as shown in Figure 2(a). Clients communicate with IEEE 802.11 wireless routers placed in buses that act as mobile nodes, Figure 2(b), and also as data mules. They receive and store users' data until they are able to forward these data, i.e., when a bus is within the transmission range of one of the installed RSUs, which are wireless routers placed in bus stops and light poles, they transmit data. The road side units, Figure 2(c), form a wireless mesh network to provide Internet access. Currently, we have only one gateway to the Internet, which is a RSU connected through UTP cable to the Ethernet local network of GTA lab. Mobile nodes and RSUs run

OpenWrt OS [5], for which there is already a DTN protocol stack implemented [6]. Mobile nodes are also equipped with USB pendrives because they must store users' data during connectionless periods. The proxy server developed by the ReBUS team works between the hybrid network and the Internet. It converts DTN bundles received from buses to IP datagrams to send them through the Internet.

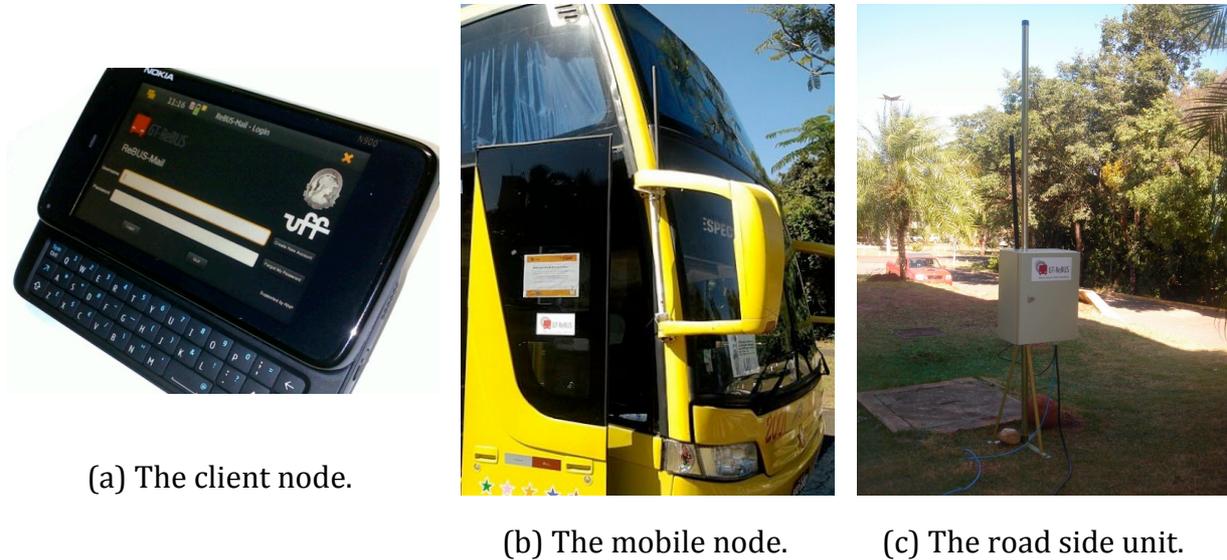


Figure 2: The equipments used in the ReBUS prototype.

IV.2 ReBUS Applications

We have developed three applications as a proof of concept: the message exchange, the content distribution, and the transit information applications.

The message exchange application allows users of the vehicular network to send emails to other users who have a valid email address on the Internet. Figure 3 details how this application works in four steps and also illustrates the ReBUS prototype architecture as described as follows:

- Step 1 – Users equipped with client nodes execute the message exchange application. Thus, users are able to write a message anytime and anywhere, if they are connected or not to the network. To provide this functionality, each client node runs the DTN protocol stack in order to store messages in case there is no connection with one mobile node. As soon as the client node is within the range of the mobile node, messages are transmitted from the user smartphone to the router inside the bus.
- Step 2 – Mobile node is acting as data mule. A bus carries messages during connectionless periods, i.e., it is out of the range of a RSU.
- Step 3 – When the mobile node is within the range of a RSU, messages stored in the router inside the bus are transmitted to the router placed in the bus stop. The time the bus is “in contact” with the RSU ranges from dozens of seconds to a few minutes.
- Step 4 – The road side unit sends messages to the gateway. These messages are forwarded through the wireless mesh network by using multihop communication if necessary. Finally, the gateway forwards bundles to the proxy server. This server

converts the received bundles into IP datagrams and connects to the default mail server to send messages created based on the information extracted from these bundles. The proxy is always connected to the Internet. The mail server is responsible to forward messages to the given recipients. For simplicity, the same machine acts as gateway, proxy, and mail server in Figure 3.

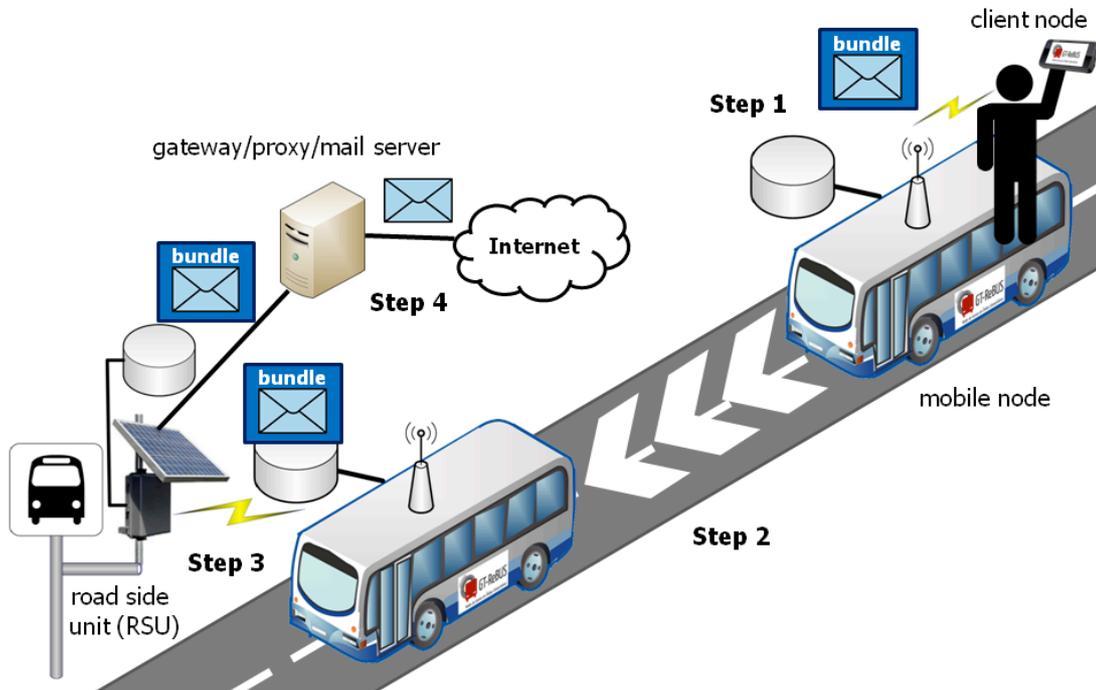


Figure 3: The ReBUS prototype architecture and the message exchange application running.

The second application developed is focused on the content distribution. We assume that mobile nodes, i.e., the wireless router inside buses, are able to run a light web server and thus host several web pages. These web pages may be used for institutional announcements or even for commercial purposes. The challenge in this case is how to update these web pages frequently. With our application, pages can be updated automatically without human interference. Periodically, the proxy server keeps track of changes in given web page hosted in a server on the Internet. If the page content changes, the proxy download the modified page. The next time a mobile node gets in contact with the proxy, i.e., the bus is within the transmission range of a RSU, this modified page is automatically uploaded to the web server inside the bus. After that, this new page is available to client nodes.

The third application developed aims at providing transit information to users in real-time, such as the estimated arrival time of buses in a given bus stop, the traffic jam between two bus stops, etc. Users of this application access the entire road map of a given bus itinerary and also view the arrival time of buses through a simple and user-friendly interface. The first experiments with this system were conducted through simulation but we are planning to make it operational in the UFRJ campus as soon as possible.

V. Conclusion

In this letter, we have described the scenario and technical solutions to implement a vehicular ad hoc network using buses in the campus of UFRJ, Rio de Janeiro, Brazil. Our ReBUS prototype is based on three pillars: the use of off-the-shelf IEEE 802.11 equipment, open-source software, and the combination of ad hoc and DTN forwarding techniques. We have demonstrated the viability of such a solution through the development of two simple applications, an email client and a content distribution proxy. We are currently in the process of deploying a fixed infrastructure using solar-powered IEEE 802.11 routers. With this vehicular network testbed in place, our next step will be to develop specific routing protocols and applications.

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