RasPiNET: Decentralised Communication and Sensing Platform with Satellite Connectivity

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ABSTRACT

This paper introduces the RasPiNET, which forms a Delay Tolerant Network consisting of Raspberry Pi computers. Each Raspberry Pi node equips WiFi communication capability together with a battery pack and RasPiNET can operate a data mule communication. Sensing devices such as RFID tags or mobile phones can store the sensed data to the nearby RasPiNET node, and the data mule operation can be carried out to deliver the collected data to the data processing computer. Furthermore the satellite devices can be integrated to the RasPiNET node. RasPiNET can be deployed in the remote region or developing countries.

Categories and Subject Descriptors

C.2.4 [**Computer Systems Organization**]: Computer Communication Networks—*Distributed Systems*

Keywords

Delay Tolerant Networks, Satellite Communication, Data Collection, Remote Sensing, Data Mule

1. INTRODUCTION TO RASPINET

In our Haggle project [8], we explored a proximity based communication, where the communication in highly stressed settings with intermittent connectivity, variable delays and high error rates in decentralised and distributed environments over a multitude of devices that are dynamically networked. In this paper, we carry out the concept of such proximity based communication and introduce a Raspberry Pi based decentralised network (RasPiNET), where we use Delay Tolerant Networks (DTNs) as communication base. RasPiNET consists of any number of Raspberry Pi, a tiny computer equipped with a 700 MHz ARM11 CPU, 512 MB of RAM, an Ethernet port, two USB ports, an SD card port for storage, and several GPIO (General Purpose Input Output) pins. Various communication media such as Ethernet, WiFi Adhoc, WiFi Direct, and Software Access Point can be deployed. In the current prototype of RasPiNET, we use a software access point approach, where a Raspberry Pi acts as an access point and the other Raspberry Pi nodes connect to it as clients. The Raspberry Pi server (or access point) is configured using hostapd [4], which creates a software based access point. It provides the WPA compatible encryption. For WiFi communication, hostapd compatible USB WiFi dongles (e.g. TP-LINK TL-WN723N [6]) are used.

RasPiNET allows the devices to exchange messages between devices and it supports long delays and disruption on paths when forwarding and/or delivering messages. Depending on the forwarding algorithm, the messages will be spread to the other node in epidemic manner or will follow an policy to only forward a message to selected nodes.

To make it portable and easy to deploy at any location, we can use a battery pack with a Raspberry Pi. A Raspberry Pi has low energy consumption, as it only draws 3.5W. We have tested energy consumption of Raspberry Pi with a battery pack with a capacity of 7000 mAh. The average duration of the battery was around 10 hours, enough for a continuous measurement and collection of data during daylight.

RasPiNET can be used for various purposes. As an example, we explore RasPiNET as a sensing platform. Sensing devices could be RFID tags, Bluetooth devices or mobile phones. We have experimented using active RFID tags manufactured by OpenBeacon [9] as proximity sensing devices and the RasPiNET node is used as a reader for the RFID tags. Fig. 1 depicts a OpenBeacon RFID tag. The collected data in each RasPiNET node are sent to the data processing node and the decentralised and standalone RasPiNET allows the sensing platform to be deployed anywhere.

Figure 1: **OpenBeacon RFID Active Tag**

Building RasPiNET is relatively inexpensive. Building up a node of RasPiNET for USB interfaced RFID tag reader costs around 60GBP. The Ethernet based reader costs 150GBP, which has to be deployed where Ethernet port is accessible (see Fig. 3 for the cost of RasPiNET node: 1.

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Figure 2: **RasPiNET Data Mule with Satellite Connection**

Raspberry Pi 2. OpenBeacon USB reader 3. Battery Pack (7000mAh) and 4. WiFi dongle 5. SD Card 6. LED).

In the current prototype, we have implemented a data mule communication paradigm using DTN2 bundle protocol [3]. Most of the nodes are stationary and a few nodes move around, following the route that intersects the stationary nodes. These moving nodes are called ferries or data mules and the role of them is collecting data from the stationary nodes. This approach is widely used for data collection in sensor networks. Another example is the the postman example in rural regions. The postman carries (or on his motorcycle) a node that collects and delivers messages to the other nodes in a rural village, where there is no internet access. People living in such village can send and receive emails, social networks updates, digital newspapers, etc, without having internet access, in delay tolerant manner.

RasPiNET can also integrate the satellite device. We have prototyped using a RockBlock [10], which equips a serial port connection to Raspberry Pi. The RockBlock device works via Iridium Satellite Network and simple command interface is provided for the operation, where the interface between FA (Field Application) and ISU (Iridium Subscribe Unit) is a serial connection with extended proprietary AT commands. Iridium Short Burst Data (SBD) session occurs roughly every 10 seconds and it is available anytime from any coordinate on the earth. RockBlock also provides email and web service based messaging services, where it could be less than 0.03 EUR per 34 bytes of message (Hex encoded).

2. SENSING PLATFORM

The active RFID tags can be used to measure the mobility of people and interaction of them. We have used the RFID tags by OpenBeacon [9] and built a sensing platform that

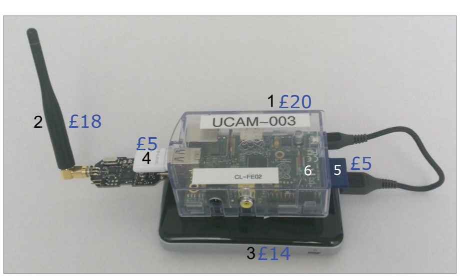

Figure 3: **Raspberry Pi with WiFi, Battery, and RFID Tag Reader**

will be used in the nursery, hospital, or remote villages in developing countries.

The collected data is extremely useful to model the movement of people for understanding the spread of infectious diseases. The built sensing platform does not require external power supply or Internet connectivity, where we install them inside a water proof plastic box to make it resistant to rain, dust, etc.

3. OPENBEACON RFID ACTIVE TAGS

An OpenBeacon RFID Tag [9] is an active RFID tag that transmits signals in the 2.45 GHz band using an nRF24L01 transceiver. The nRF24L01 [2] can transmit beacons at different power strengths: -18dBm, -12dBm, -6dBm, and 0dBm. Different power strengths are used to estimate the distance between tags and the RFID readers. These RFID tags can detect beacons from other tags and it is used to measure face-to-face contact. These contacts are stored in a memory of the RFID Tag and a report message is sent periodically to the readers.

4. DELAY TOLERANT NETWORKS USING RASPBERRY PI

RasPiNET uses the Bundle Protocol (RFC5050) [11], an overlay network protocol situated in the application layer that implements the Delay and Tolerant Networking properties using bundles (messages). Several implementations of the Bundle Protocol are available as open source software [1]. The reference implementation, DTN2 [3], has been developed by the Delay Tolerant Networking Research Group (DTNRG). It is the most robust implementation, compatible with Linux and OSX, and prepared for real-world deployments. ION (Interplanetary Overlay Network) [5] is another popular implementation, being more lightweight than DTN2, as it was designed for its use in embedded systems, especially for extraterrestrial communications on satellites and spacecrafts. ION is compatible with Linux, OSX, and Windows, among others. It provides compression of the bundle header for links with small bandwidth, but at the same time its TCP Convergence Layer is compatible with DTN2 implementation. Another relevant implementation is IBR-DTN [7], developed to be portable, and designed to run in systems with low specs. IBR-DTN has been reported to work to be compatible with Raspberry Pi. We used the latest version of DTN2, which offers different types of discovery agents.

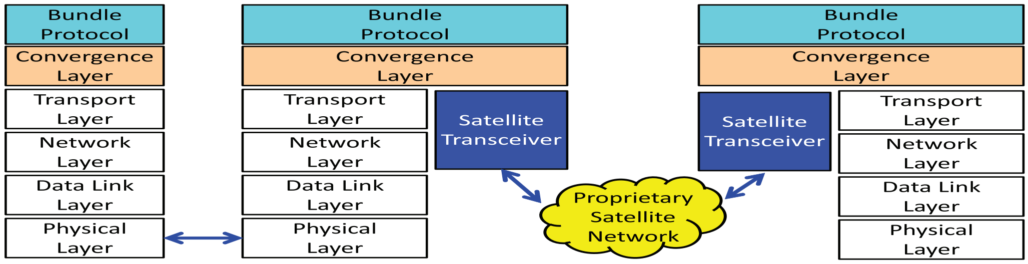

Figure 4: **RasPiNET Communication Protocol**

Data mule: Data mule is a concept extracted from Delay Tolerant Networks (DTNs) [12]. It consist of one or several mobile access points. These can send and receive messages from other static or mobile devices such as sensors or, in this case, Raspberry Pi. When a Raspberry Pi acting as a data mule passes next to one of these devices, a connection is produced and the data is sent to the mule from the Raspberry Pi equipped with sensors. The data mule can move around collecting and exchanging messages with other Raspberry Pi (see Fig. 2).

5. SATELLITE DEVICE INTEGRATION

In some scenarios, we want to have a fast way to send and receive messages over long distances, without requiring to go across the earth surface that separates two points from peer to peer. We have integrated a satellite transceiver with Raspberry Pi via USB connection using a RockBlock [10]. Messages sent to the transceiver are sent to the Iridium satellite network and received in two possible places: a) a webservice, and b) an email. Internally these messages are received in an Iridium ground station, forwarded to Rock-Block's servers, and then forwarded again to our configured web service or/and email addresses. Fig. 5 shows a scheme for message transmission over satellites.

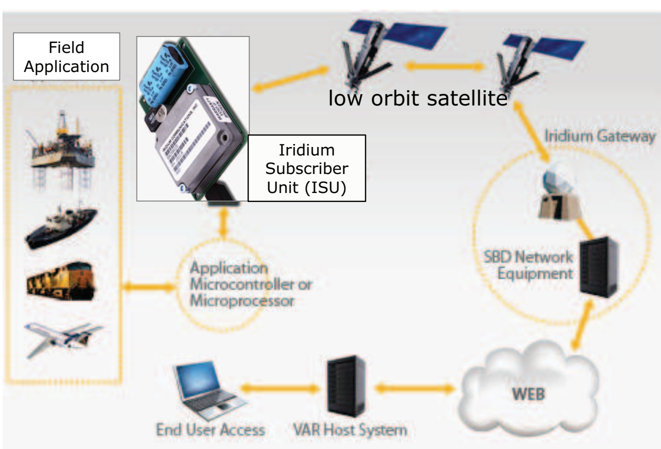

Figure 5: **RockBlock Iridium Satellite Network**

Communication protocol: RasPiNET integrates satellite communications to delay tolerant networking. The satellite transceiver we own uses one of the largest satellite constellations, Iridium, available 24/365 from almost any coordinate on earth.

Fig. 4 shows the communications between layers. The new convergence layer proposed will communicate with the satellite transceiver that will be in charge of the lower layers when communicating with a satellite. The new convergence layer will share layer with other convergence layers (TCP, Ethernet, etc), thus making the device fully compatible with delay tolerant communications using other interfaces apart from the satellite one as shown.

6. SUMMARY AND FUTURE WORKS

We have introduced RasPiNET, which is a decentralised delay tolerant communication network, which can be deployed in remote regions, where there is no power supply or Internet connectivity. Currently, we are working on extending RasPiNET to provide multicast feature, efficient data aggregation and compression, in-network data processing, and further flexible satellite communication capability.

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