Using Bluetooth Scatternet for Automatic Meter Reading: A Wireless Network Application in Telemetry System

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Abstract: - The energy distribution companies have thousands of meter devices spread out over large geographic areas. A telemetry system that allow them to control and monitor all those devices from a central point would be certainly of great help for optimize their operation. In this way, those companies could not only automatically collect their customer's energy consumption data, but also remotely control the energy distribution and monitor the service quality level offered to each residence or region, just to mention some possibilities. A fundamental requisite to reach that functionality is the interconnection of all energy meters and other control devices through a data communication network. However, the wide geographic area of the electric energy distribution network combined with topological complexity and high capillarity has been a challenge to be overcome in the way to permit the large use of such telemetry systems. Cable-based network solutions are often expensive and non-practical for those cases. A wireless network could be an alternative. The Bluetooth wireless technology is quite promising as a short-range communication solution. In spite of the apparent paradox, there is an open opportunity to apply the Bluetooth technology strengths in building wide area data communication networks to support telemetry of energy distribution services, including Automatic Meter Reading (AMR), as also other applications involving dispersed electronic devices. In this paper we are considering the use of Bluetooth technology in such new scenario.

Key-Words: - Bluetooth wireless technology, Telemetry, Automatic meter reading, Wireless network, Scatternet, Monitoring and control of energy distribution, Short-range wireless communications.

1 Introduction

The electric energy distribution companies are facing great challenges, especially in Brazil. Run over by the crisis of energy by which the country has recently gone through and because of the new current rules of acting resulting from the privatization process, those companies are now, more than ever, being impelled to look for new ways to optimize their operation and maximize the service quality, as a condition to guarantee its profitability and survival in a critical market involving an absolutely essential service for any modern society. Therefore, the possibility of counting on automated tools and detailed information about its customer's profile takes more and more importance for those companies, as a form to reach a more effective acting. In that context, the use of a telemetry system of electric energy distribution services becomes a key factor to obtain greater operational effectiveness. However, a telemetry system of that nature depends on availability of a wide area and high capillarity data communication network, just as the own energy distribution network. Additionally, that communication network should be of low cost and easy to maintain. Those requirements characterize a challenge that still needs to be overcome, not only for the Brazilian electric sector, but also for most of the energy distribution companies in the world.

The wireless technology Bluetooth is a short-range communication solution oriented for PAN (Personal Area Network) applications. The technology is quite recent and promising as a connectivity solution for personal electronic devices, especially due to the growth of the use of mobile devices. The Bluetooth

specification contemplates several models of use of the technology. The primary scenario foresees the use of Bluetooth to substitute interconnection cables among personal devices, such as notebooks, cellular telephones, PDAs, digital cameras, and similar. Other scenarios include the use of the Bluetooth technology to allow the connection of personal devices with access points of Local Area Network (LAN), to access remote services through a cellular telephone connection, and to make ad hoc connections among personal devices [1].

In this paper, we will consider a new scenario for applying the Bluetooth technology. Our proposal is focus the use of the Bluetooth technology for constructing a wireless data communication network that should give support to a telemetry system for electric energy distribution services in urban zones.

The paper is organized as follows. In Section 2 we present the mentioned application scenario and make a brief overview of the Bluetooth technology on Section 3. Section 4 comments our vision of a telemetry system for energy distribution services based on Bluetooth, and finally we draw some conclusion on Section 5.

2 Scenario of the Application

The reorganization process of the electric sector, worsened by the recent energy crisis by the which Brazil has gone through, deepened some existent problems and introduced new ones to the electric energy distribution companies. However, the recent Brazilian experience showed that there are some basic difficulties that must be overcome by all energy distribution companies. Among them we can mention:

- High levels of global losses of energy;
- Frauds;
- Default;
- Low automation in energy distribution and control process;
- Manual readings of energy consumption data (generally a monthly process);
- Expensive maintenance of the energy distribution network;
- Lack of information to compose a daily profile of each customer's consumption;
- Lack of individualized information about the quality of the service provided;
- Impracticability of adopting the "yellow fee" (different values depending on the consumption timetable); and
- Difficulty to compose cross consumption profiles (by region, kind of consumer, customer's incomes class, and so on).

It is interesting to observe that the lack of information, especially the detailed consumption information of each residence, is an important aspect to be considered, because it brings difficulties for several management processes: from the technical areas (like operation, engineering and planning) to the commercial and marketing areas. Those problems, deficiencies and needs end up turning the company's operation more onerous and less effective, jeopardizing its profitability and, in some cases, its own survival in the market. We can also observe that some of those aspects are not only a privilege of the Brazilian companies, but still characteristic of the electric sector in a large part of the world.

In that context, the effort of getting adequate solutions has showed that there is a great need of telemetry systems for electric energy distribution services. Those systems comprise the use of consumption electronic meters and other control devices, linked to a communication network, to collect consumption registers and carry control signaling. This network must have the same inclusion and capillarity of the own electric energy distribution network that will be monitored and controlled. Clearly, it is a great challenge implement all this in a large scale, low cost manner. Actually, the issues involving energy Automatic Meter Reading and Distribution Automation System (DAS) are fundamental and strategic for the future of the energy distribution companies. Every time with more frequency and intensity, government and energy companies will be claimed by the society in the sense of getting better management processes, in such a way one can have minimum guarantee about constant energy availability, as it is demanded, and with affordable price to the whole population, since it is a essential service indispensable to the modern way of life. As well known by the Brazilians, now more than before the crisis.

Due to the importance for the energy distribution companies all over the world, the industry has invested in solutions for automatic measurement of energy consumption, especially, in the case of great consumers. But, as far as we know, there are no large-scale solutions

implemented for small consumers. The key issue is how to obtain solutions that are not only better from a technological point of view, but also that present a compatible cost benefit. The matter about cost is easier to be solved when dealing with great consumers, like certain industries, where in only one point (meter) is generated revenue high enough to permit the energy companies to invest in an automated solution, as it has already been happening in the practice. In a similar way, the great vertical condominiums can receive equivalent approach, no matter if they are commercial or residential.

The great challenge is to find solutions that are appropriated for use in areas of smaller consumption density and great geographical dispersion, as usually it is found in flat residential areas. In other words, the challenge is to interconnect the residential energy meter devices in a high capillarity data communication network, but maintaining a low medium cost per consumer. Actually, the situation here is similar to challenges already known and referred to by the telecommunications industry as the "last mile challenge". This expression summarizes the existent difficulties to apply available technologies in the offering of more telecommunication capacity in each residence, but at an acceptable cost.

Those conditions indicate that Bluetooth technology, for its technical characteristics, its low unitary cost, and small size, could be a good alternative to be aggregated to the energy meter and control devices, thus providing a high capillarity communication network which would support the demands of centralized telemetry system of energy distribution.

3 Bluetooth Technology

The Bluetooth technology resulted from the joint effort of a group of companies that, starting from researches from Ericsson, aimed to establish a free-license open-standard for communication among devices. These devices should be available in a global scale, and should be based on a single chip, which would lower their cost (the goal is less than 5 dollars). They should also be small in size, having low energy consumption, in a way that they could be embedded virtually in any electronic device, particularly the mobile devices, as cellular and PDA's. In 1998, the Bluetooth SIG (Special Interested Group) was created to develop that technology. Nowadays, companies like Ericsson, IBM, Toshiba, Nokia, Intel, Motorola, Microsoft, and 3Com support that group. In addition, approximately 3.000 other companies have already adhered the standard [1].

The Bluetooth technology, whose current specification is version 1.1 published in February 2001, is based on a standard protocol stack and a radio that operates in the license-free 2.4 GHz ISM band, which is available globally, using frequency-hoping spread-spectrum techniques, at a rate of 1.600 hops per second. These characteristics combined with the adoption of a small size packet provide a good immunity against interferences from other equipments operating in the same band. The radio has a range from 10 to 100 meters, depending on the device class. However the most common is class 3, which is limited to 10 meters. Its baseband protocol is a combination of circuit and packet switching. It has capacity to establish synchronous and asynchronous communication channels, with support for voice transmission (up to 3 channels PCM at 64 Kbps) and data transmission, through symmetric channels (433.9 Kbps each one) or asymmetric ones (723.2 Kbps to 57.6 Kbps). The maximum speed in the air is 1Mbps, but the effective payload is lower (estimated 721 Kbps) [1][3].

The network formed by the connection of two or more Bluetooth devices is called *piconet.* The piconets are characterized by having a star topology where one of the participant devices is defined as being the master and the others the slave. Each piconet supports the connection of up to 255 devices, but at most 7 slave devices actively communicating with the piconet's master are allowed. There is also the possibility of a device participate concurrently as a member of more than one piconet. In that way, it is possible to connect several piconets to each other, forming what is called a *scatternet*. Through the scatternets one can reach a wider geographic area, or, if the scatternets share the same area, it will be possible to establish communication among a greater number of devices [2][3].

The Bluetooth technology has also some security resources, which can be used to control and protect the connections among the devices. Those resources include authentication keys, encryption, Personal Identification Number (PIN) and the use of security resources offered by protocols transported in the superior layers or by application layer.

4 Using Scatternets in Automatic Meter Reading

As mentioned in Section 2, a telemetry system could address important demands of the energy distribution companies and Bluetooth seems to be an adequate technology to respond to these demands, making the communication among the devices in the network possible. In the following, we will present an overview of our proposal, commenting some aspects about the telemetry system for energy distribution and about the use of scatternets to reach an adequate solution to the problem of obtaining a low cost and high capillarity network that can support such system.

4.1 The Telemetry System Proposed

Our proposal contemplates a centralized telemetry system for energy distribution services, based on electronic devices for energy measurement and distribution control, which are interconnected through a wireless communication network. Not only would that communication network allow automatic and constant collect of the consumption data (sending them to central server), but it would also become possible the transport of signaling and control messages allowing certain interventions on the electric network to be done remotely, like the activation and deactivation of energy supply to a specific residence, for example. It would also be possible to automatically collect registers about certain events, as alarms of safety against attempts of device violation or energy supply interrupts, besides all information needed for composing quality of service indicators required by ANEEL (Brazilian's National Energy Agency) [9].

In that solution drawing, the electronic meters (multiple or single) could be placed directly at the posts in order to prevent fraud attempts and get more safety and low cost. It is also important that the meters should be small devices with low energy consumption. The support to remote commands allows the company to obtain operational gains and to improve the default management process. The proposal of a wireless network, at least in the "last mille" segment, aims for low cost and maintenance facility. Alternatives like PLC (Power Line Carrier) technology are a promise yet, and it has great obstacles to overcome till it becomes widely used due to the diversity of power line characteristics. The use of coax cable, for example, is very expensive (preliminary estimates indicate average costs above US$ 55.00 by attended post) and would have maintenance problems, including because other shares the same post infrastructure.

The existence of a central database supporting the customer's detailed consumption data would give several advantages for the company's operation management. It would also be possible to offer more information to their customers, even through alternative channels. Imagine, for example, that during the recent energy crisis the Brazilian consumers could monitor the evolution of its energy consumption just consulting its position by a phone call, or by Internet, from home or office, or even from any place through a cellular phone, by voice or WAP. Other alternatives of services are also facilitated by the system proposed. For instance, we could suggest the development of an alternative for pre-paid energy supply, which could be offered with low cost and great operational facility. And, if we think in a long-term view, there is a good chance to integrate gas and water meters in the same wireless communication network.

4.2 The Communication Network to Support the Telemetry System

Considering the mentioned solution scenario, a combination of characteristics made us think that we had here an interesting potential for applying the Bluetooth technology, especially as part of the communication solution for the larger capillarity segments of the network.

We observed several characteristics that correspond to the requirements, like low cost, small size and low energy consumption; besides flexible communication channels with throughput large enough to carry the traffic generated by the meter devices, central server and other control devices. In addition, there are the advantages provided by a standardized open technology, which operates in a free-licensing globally available band, and is supported by important players of the electronic and telecommunications industry. It is a complete package solution, including interoperability guarantee among devices from different suppliers.

The main point to be solved would be the distances involved in an electric energy distribution network, because the Bluetooth technology focus is on the short-range connectivity. The solution that we are considering assume that there will be at least one class 1 Bluetooth device not further than 100 m from the other. That

device, planned to be put at the post, would be the own energy meter with a Bluetooth interface, or, in some cases, a specific Bluetooth device used to allow the interconnection among energy meters that are more than 100 m faraway. That device should be connected to the devices in the neighboring posts, which in turn should be successively connected to their other neighbors (see figure 1). Connecting hundreds of piconets in this way (creating scatternets), a long distance could be covered reaching up to concentration points. Those scatternets, being appropriately dimensioned and configured to carry the foreseen traffic, could cover geographical areas with some kilometers of radius. The aggregated traffic in the concentration points could be carried away by any appropriated network solution, since they would be already out of the typical "last mille" area.

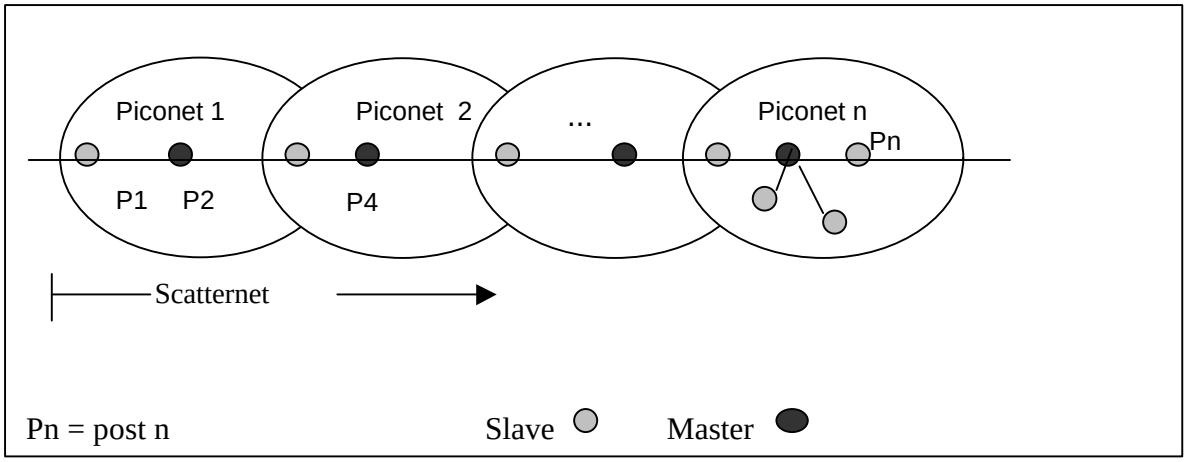

Figure 1 – A scatternet along the post line

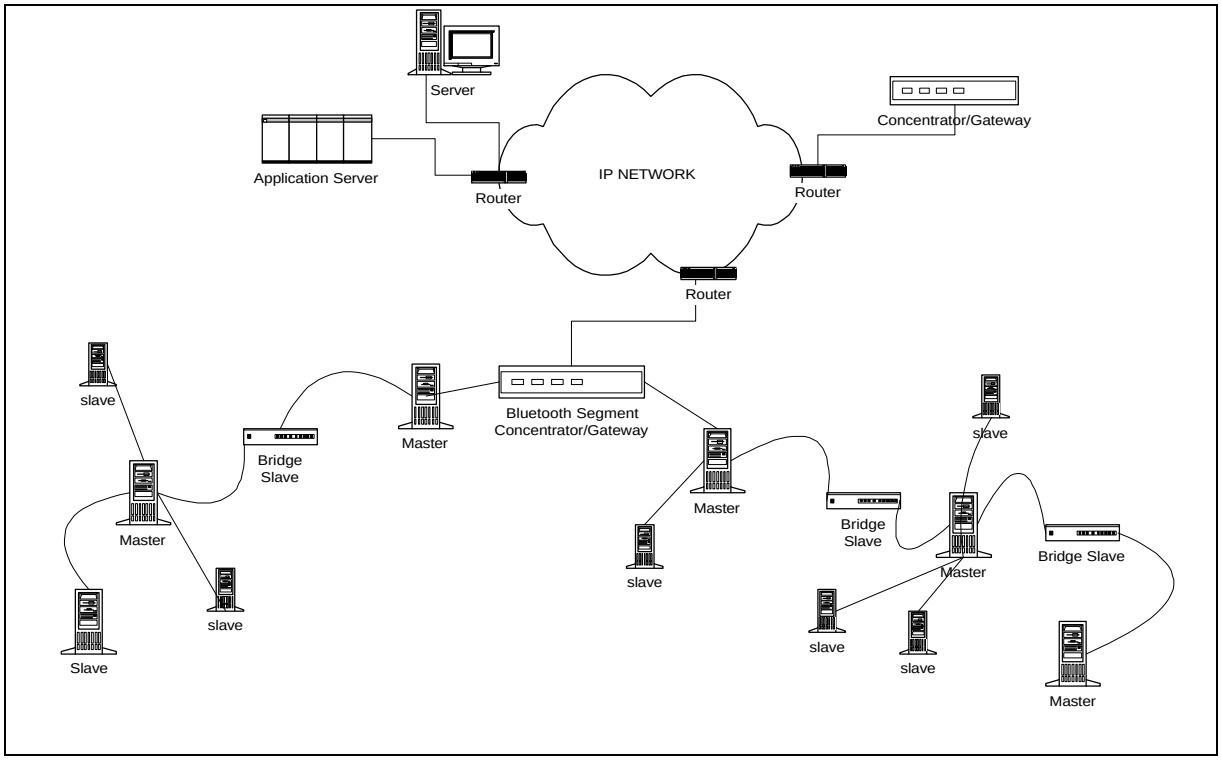

Figure 2 – Bluetooth network segments connected by a concentrator/gateway to IP Network

In case of companies that don't have or don't want to work with electronic meters at the post, a slightly different scenario can be offered. Just consider that the energy meters put in the residences would be interconnected to a specific interconnection device at the post, or they would be directly interconnected to each other. In any case, they all would be using a Bluetooth interface for communication among them.

Other important aspect is the definition of the best topology and routing schema. Actually, there is no generic solution established for that issue yet. Initially, for this specific case, we intend to set a sequence of interconnected piconets along the posts, forming network segments up to the concentrator node (see figure 2). That node would be an access point to one IP network comprising the set of concentrator nodes and the processing nodes (central or distributed servers). In that way, the telemetry system messages would reach their final destination "hopping from one post to other" in the Bluetooth network segment. In other words, they would follow from one piconet to another through a bridge node (Bluetooth device that participate in more than one piconet). The definition of the length of each network segment should be based on traffic volume predicted for each area. We are currently working on a definition of an appropriate routing protocol that guarantees the exchange of messages among central servers and the applications located in devices distributed along the energy network. We are studying some variations in the way of establishing scatternets to find the best topology and evaluate its influence in routing algorithms and network performance.

There is still a particular aspect in that Bluetooth application scenario that must be considered. The electric energy network presents a great complexity due to the wide geographic dispersion, but it has stable connections. This means that once a topology and an appropriate configuration of channels are defined, the connections can be established and will not change often. Even so, it should exist an application for mapping the devices and connections available in each area and for establishment of the connections conform the topology adopted.

5 Conclusion

We saw in this paper that the current demands of the energy distribution companies propitiate a singular opportunity for applying the Bluetooth wireless technology in covering a wide geographic area to support the communication needs of telemetry systems. This fact opens space to a new scenario for Bluetooth use, distinct from its original vocation, which is the Personal Area Network (PAN) and also distinct from mobile ad hoc network, that is other increasing important area where Bluetooth technology tends to be applied.

We aimed to demonstrate the viability of applying that technology to build a wireless data communication network able to interconnect electronic devices geographically dispersed, as it would be the case of the electric energy meters. The work that we are developing has the goal of studying Bluetooth scatternets to support the development of a wireless application in automatic meter reading area. However, the telemetry system in energy distribution services we have mentioned is also being used as reference model of study, since eventually we expect not only to obtain a new alternative solution for this particular case, but also extract rules and heuristics applicable in other network projects involving devices spread over wide areas, for instance, safety sensors, seismographs, environmental monitoring, water meters, gas meters, and so on.

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