Mobile Ad Hoc Networks for Ubiquitous Computing: Review

Ricky Mohanty¹, Abhimanyu Jena², Jibanananda Mishra³
¹ETC, OEC, BPUT, BHUBANESWAR, ODISHA, INDIA
²ETC, BRMIIT, BPUT, BHUBANESWAR, ODISHA, INDIA
³ETC, OEC, BPUT, CUTTACK, ODISHA, INDIA

ABSTRACT
The term “ubiquitous computing” refers to making many computing devices available throughout the physical environment, while making them effectively invisible to the user and its aims to create surroundings, transparent to the user, where devices with communication and processing capacity (cellular phones, PDA, sensors, electrical appliances, electronic books, etc.) can cooperate in an intelligent and context-aware manner. Communication plays a fundamental role in this field and in particular mobile ad hoc networks (MANETs) can provide flexibility to the access. This paper presents the concept of experiment relative to the use of the Bluetooth and IEEE 802.11 wireless technology to build a MANET which provides network support to a context-aware application.

Key Words: Ubiquitous Computing, Mobile ad hoc networks, Bluetooth, IEEE 802.11

1. INTRODUCTION
The term “ubiquitous computing” refers to making many computing devices available throughout the physical environment, while making them effectively invisible to the user [1]. Ubiquitous computing cannot always use traditional enrolment schemes, especially in mobile ad hoc networks (MANETs) and global computing infrastructures. Thanks to the advances in devices processing power, miniaturization and extended battery life, and the proliferation of mobile computing devices the goal of ubiquitous computing becomes every day more realistic. Ubiquitous computing environments imply MANETs but include all other kinds of networks as well. For example, the current IPv4 based, NATed, Internet will most likely provide the foundation of any global computing environment. Many authentication protocols have been developed to verify the identity claimed by a principal especially arise in MANETs and ubiquitous computing and which do not arise in more traditional networking contexts. Strongly related to ubiquitous computing is context-aware computing. In context-aware computing, the applications change or adapt their functions, information and user interface, depending on the context (by inferring or sensing it), the client, and possibly the moment in time [2]. Communication plays a fundamental role in this field and in particular mobile ad hoc networks (MANETs) can provide flexibility to the access. MANETs are wireless networks with no fixed infrastructure. Nodes belonging to a MANET can either be end-points of a data interchange or can act as routers when the two end-points are not directly within their radio range. Such a network may operate in a stand-alone fashion, or be connected to the larger Internet. The ad hoc architecture has many benefits, such as self-reconfiguration and adaptability to highly variable characteristics such as power and transmission conditions, traffic distribution variations, and load balancing.

2. AD HOC NETWORKING
An ad hoc network is a network with temporary plug-in connections, in which the network devices are part of the network only for the duration of a communications session or, in the case of mobile or portable devices, while in some close proximity to the rest of the network. Ad hoc network is often local area network or other small area network formed by wireless devices. In Latin, ad hoc literally means "for this," further meaning "for this purpose only," and thus usually temporary. The term has been applied to future office, home and personal area networks in which new network nodes can be quickly added and removed. [1] The area of ad hoc networking has gathered much research interests in the past years. Many studies have concentrated on the routing issues of ad hoc networking [2]. The history of wireless networks started in the late '70s and the interest has been growing ever since. During the end of the last decade, the interest has almost exploded probably because of the fast growth of the Internet. The latest developments are centered around infrastructure less wireless networks, more commonly called ad hoc networks. The word “ad hoc” despite it could be translated with negative terms like “improvised” or “not organized”, in this context only describes an higher level of flexibility. All nodes within an ad hoc network provide a “peer-level multi-hopping routing” service, to allow out-of-reach nodes to be connected. Contrary to a wired network, nodes in an ad hoc network can move thus making the topology variable and introducing changes often unpredictable. This fact creates many challenging
research issues since the objectives of how routing should take place is often unclear because of the many different parameters to be taken into consideration, like bandwidth, battery power and because of the demands like low latency or QoS. The routing protocols used in ordinary wired networks are not well suited for this kind of dynamic environment. They are usually built on periodic updates of the routes, creating a large overhead in a relatively empty network, causing a slow convergence of changes in the topology. Recently, given to the interest aroused by ad hoc networks, the Internet Engineering Task Force (IETF), started a new dedicated work-group denominated Mobile Ad hoc Networking group (MANET) [10], whose main objective is to stimulate research in this area. If until a couple of years ago near to 60 proposals of routing protocols were being evaluated, nowadays only four proposals, respectively the “Ad hoc On Demand Distance Vector” (AODV) [11], the “Dynamic Source Routing for Protocol Mobile Ad hoc Networks” (DSR) [12], the “Optimized Link State Routing Protocol” (OLSR) [13], and the “Topology Broadcast based on Reverse-Path Forwarding” (TBRPF) [14], have resisted to the competition; AODV and OLSR have reached the ”request for comment” (RFC) level. AODV and DSR offer routing under demand, that is the routes for a determinate destination are only calculated whenever they are requested. The algorithms under demand try to reduce the overload by diminishing the number of periodic update packets that are sent in the network, by determining routes only when they are necessary. The main disadvantage of these algorithms is the initial delay they introduce, being this a limitation for those interactive applications that require a specific level of quality of service (e.g., audio and interactive video). OLSR and TBRPF offer proactive routing, that is all the routes to all the possible destinations are calculated a priori and are updated using periodic messages. These protocols introduce a fixed level of overload but they allow routes to be offered almost instantaneously. Even if the protocols before mentioned solve the problem of routing at the data link layer, much work has still to be done to optimize their operation in order to be efficiently used for ubiquitous computing.

![Image](image.png)

**Fig 1:** Piconets with single slave operation (a), multi-slave operation (b) and scatternet operation (c).

### 3. BLUETOOTH TECHNOLOGY FOR AD HOC NETWORKING

Bluetooth is one of the technologies that can be used for ad hoc networking. Bluetooth specification is a computing and telecommunications industry specification that describes how e.g. mobile phones, computers, and personal digital assistants (PDAs) can easily interconnect and communicate with each other by using wireless transmission in a short-range. The goal of the specification is to eliminate the need for any cable connectivity and promote ad hoc networking. By using this technology, users of cellular phones, laptops, PDAs, etc. portable devices can quickly share information with each other, for example, in a conference room using ad hoc networking. The key features of the Bluetooth specification include robustness, low complexity, low power, and low cost. Bluetooth requires low-cost, down to $5, transceiver chip be included in each device. According to the specification, when two Bluetooth devices come into each other’s communication range, one of them assumes the role of master of the communication and the other becomes the slave. This simple “one hop” network is called a piconet, and may include up to seven active slaves connected to one master. As a matter of fact, there is no limit on the maximum number of slaves connected to one master but only seven of them can be active at time, others have to be in so called parked state. [5] See Figure 1 for basic piconet topologies introduced. The specification also allows multiple roles for the same device, i.e. a node can be a master in one piconet and a slave in another. This permits the connection of several piconets as the nodes functioning in master/slave mode act gateways between piconets. In the Bluetooth concept the network topology resulting by the connection of piconets is called a scatternet. A node can be active in only one piconet at time, and to
operate as a member of another piconet, a node must switch to the hopping frequency sequence of the other piconet. Bluetooth technology has appeared as a promising platform for ad hoc networking. The core protocol specifications and architecture of Bluetooth are defined in [8]. The Bluetooth standard is a short range and low cost wireless radio system, aimed at connecting portable devices like PDAs, mobile laptops and phones reducing the need of drawing cables between these devices. It operates in the GHz ISM band and is the baseline approach for the IEEE 802.15.1 Wireless Personal Area Network (WPAN). Bluetooth is based on a connection-oriented scheme and uses a polling scheme where a single master coordinates the access to the medium of up to 7 active slaves, i.e., a piconet. The Bluetooth specification defines two different types of links namely, Synchronous Connection-Oriented (SCO) and Asynchronous Connection-Less (ACL). The first one handles real time traffic, like voice, while the latter is commonly used for data transmission. Ad hoc networking over Bluetooth can lead to many useful ubiquitous application specially because of its ability to locate close-by devices and to discover the type of services they offer. Nodes that are close-by can find their neighbors using the inquiry procedure. After discovering close-by devices, a node can decide to page to them and to connect to them. A dedicated protocol called Service Discovery Protocol (SDP) is then used to interchange information about all the available services at each node. In a previous work [15] we designed and implemented a prototype for the OLSR routing protocol that allowed us to integrate in a unique network multiple operating systems, device types, and radio technologies. Using a specifically designed API, called PICA [16], we analyzed the development process required to obtain a multi-platform implementation of the protocol. The support for heterogeneous radio technologies was introduced with an extension of OLSR in order to support Bluetooth nodes. We showed how well this strategy performed in terms of applicability and preserving the scarce bandwidth available in Bluetooth links. The basic strategy being an implementation where no OLSR packets were required to flow through Bluetooth channels. The proposal integrated Bluetooth devices in a MANET by using a star topology. The star core being a device with high availability of resources and connectivity. The Bluetooth only nodes were kept unaware that they belonged to a MANET. The node to which they are connected to, the star core, must have both a IEEE 802.11b as well as a Bluetooth card.

Fig. 2. A pictorial representation of a possible configuration of the UbiqMuseum architecture.

4. THE UBIQMUSEUM SYSTEM ARCHITECTURE

In the UbiqMuseum, the overall network architecture is based on the cooperation of an edge wireless network and a core wireless/wired network. The edge side is solely based on the Bluetooth technology. The core network is based on the integration of a fixed Ethernet local area network and a wireless IEEE 802.11b WLAN. The OLSR modified version described in [15] is used as the routing “glue” for the overall network. The system considers three types of nodes: the museum information clients (MICs), the museum information points (MIPs), and the central data server (CDS). A visitor provided with a Bluetooth enabled PDA is the basic example of a MIC. There is a MIP associated to one or more art object. Finally, the MIPs are connected to the CDS with an “adequate” combination of Bluetooth, Ethernet or IEEE 802.11b devices. The adequacy of the configuration depends on the physical structure of the
facilities. If the user wants to see the new information he has to send his profile entered in the initial configuration process. The information point will process the request by combining the user profile with an identifier of the object the user is viewing, and it will send it to the central server. There, the request is logged and processed, and a reply is returned to the information point which relays it to the client. The search for a MIP can take place automatically, which is the default option, or on user-demand. The user can change his profile at any time, for example whether he considers the obtained information is too advanced or too basic. This allows future access to be more in line with user expectation. UbiqMuseum is build around the following properties: Java based implementation: we used the Java APIs for Bluetooth wireless technology proposed by the Java Expert Group JSR-82 [17]. JSR-82 provides a non-proprietary open application development standard for creating Bluetooth applications. More than 20 leading companies have adopted it in their devices. SQL Database support: all the information related to the art objects is stored in a SQL based database. This solution gives flexibility, ease of use, and an higher level of security and a more efficient storage support and maintenance. Flexibility: UbiqMuseum can deliver a dynamic and variable number of images and text describing an art object. The format and arrangement of the information delivered do not need to be pre-defined. Scatternet support: in a crowded museum it is expected that more than seven visitors (i.e., a piconet) can be at the same time looking at the same piece of art. In that cases an algorithm is proposed that forms a scatternet to interconnect the various piconets.

Fig. 3. Example of a topology where three Piconets are connected to form a scatternet network.

5. THE UBIQMUSEUM SCATTERNET

A client, while wondering around the museum, will continuously search for new MIPs through the Bluetooth inquiry process. When a MIP is found, it is checked for if it can offer any new information of interest by using the service discovery protocol. Try to obtain a scatternet topology similar to the one in Figure 3, where two piconets can communicate by sharing one or more “bridge” devices. These bridges may either act as a master in one and as a slave in the other or as a slave in both piconets, but not as a master in both. However most of the studies have not directly addressed the issues related to the implementation. For example, for the master/slave (M/S) bridge device in piconet 3 to operate, it should have to enter the hold mode with respect to its piconet and the active mode with respect to piconet 3. This implies that communications in its piconet will be suspended until the hold period terminates. On the other hand, to connect piconet 1 and piconet 2, the slave/slave (S/S) bridge enters the hold mode in piconet 2 and becomes active in piconet 1. During the hold time no POLL packet is sent, from the master device of piconet 2. Whenever a bridge device is active in one piconet, it buffers data packets intended for the next piconet and delivers them to the next piconet when it expires the hold time. Thus, all the messages from one piconet to another pass through these bridge device.

Siegemund and Rohs [22] showed that master/slave bridges could result in reduced throughput, while slave/slave bridges require more complex negotiation and coordination protocols between masters sharing the slave devices. Since nodes in the UbiqMuseum do not need excessive bandwidth we will use bridges devices operating only in the master-slave scheme, passing all the inter-piconet communication via the masters. Moreover, this approach allows us to simplify the inter-piconet scheduling protocols. The scatternet algorithm we propose is based on using the hold mode to allow a device to leave a piconet and to join another one without any modifications to the Bluetooth specifications. We limited a piconet to a master and a maximum of five slave devices. According to [23] using five slave devices allows a tradeoff between path length and piconet congestion. We thus reserve two connections per piconet that will
be used for bridge connections. The MIP of each art object will create the first piconet of the scatternet. When more than five clients get within reach of the same MIP, they will create successive piconets using the following mechanism. When a client device cannot join the MIP’s piconet, it will try to discover any other master that is acting as a bridge to the MIP’s piconet. If no bridge is found the device creates its own piconet acting as the master and as a bridge to the MIP’s piconet. For this new master to be discovered it will register a new service called Bridge to the MIP. The master device will periodically POLL its slaves. The bridge device periodically goes into the hold mode to relay packets from the MIP’s piconet to its own piconet members. When a client requires the associated art object information, its piconet master will relay the requested information to the MIP. To join the MIP’s piconet, the bridge enters the hold mode in its piconet and then enable the INQUIRY SCAN status in the MIP piconet. The MIP master device will discover it using the periodic INQUIRY messages. When the hold time expires, the bridge will leave the MIP piconet, and relays the received information to the slave, that is the client.

![Sequence diagram for the bridge operation.](image)

The minimum interval that the bridge will spend “outside” its piconet is calculated according to the overhead incurred by entering the hold mode, the time a bridge requires to join a piconet and the time to get the information from the MIP. This period should not be greater than the maximum hold time specified in the standard (40.9 seconds or 65440 slots). Figure 4 shows the overall sequence diagram for a bridge device. Finally, the ad hoc networks present problems of security different from the rest of networks. Prudent users might want to have a certificate to certify who is actually providing him with data. A local space like a museum might be the perfect place for intruders to get access to others devices to steal information. However, the present mechanisms of confidentiality based on a central administration that provides a control of access with authentication are hardly exportable to these networks without central services and with limited energy. More research effort must be done in order to propose new models of authentication based on the distribution of an authority certifier between the movable equipment.

6. CONCLUSION
The main goal of this paper was to demonstrate that Bluetooth might be a candidate technology as network support to provide ubiquitous context-aware services. Then extended the concept of a Bluetooth node to a scatternet and we thus introduced a scatternet formation protocol, to improve the possibilities and flexibility of the topology formation. UbikMuseum still requires a lot of work in order to make it a really deployable application. Anyway, we think it’s a reasonable test-bed where to evaluate all new features related to ubiquitous computing in a realistic scenario.

REFERENCES