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Cellular System Based Energy Efficient Middleware Architecture for Ubiquitous Computing

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Ubiquitous computing requires computing devices to assist human being in their day to day routine life activities, staying invisible from their attention. In such type of computing scenario, called Ubiquitous Computing, a very large number of computers are required to identify, connect and communicate with each other dynamically, without any break in service to their users.

Rate of energy consumption of user device is very important factor for life of battery of a device. In this paper, a design of energy efficient middleware layer has been suggested. The coverage area in ubiquitous computing environment has been divided into various cluster of cell. Basic idea behind proposed energy efficient architecture of ubiquitous computing middleware is to provide multiple wireless connection of varying proximity range to mobile users. Energy consumption of device increases with the increase in its distance from base station transceiver.

Keywords: Ubiquitous Computing, Middleware, Cellular System, Cell Cluster.

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1. Introduction

Ubiquitous Computing [1] aims to provide continual service to the users without any break, along with user mobility support. Thus the infrastructure for ubiquitous computing environment shall contain large number computers supporting transparency in service access, as in distributed computing systems, and user mobility, as in cellular systems.

these systems provide services to user over a large area, distributed over globe. However, these systems differ at the level of basic architecture. Cellular systems are designed to provide the facility of voice communication to the mobile users. Cellular system divides service coverage area into different cells. Each one of these cells have a wireless transceiver to provide wireless connectivity to its users, any where in that cell. The communication in between user and transceiver is controlled and monitored by Base Station Subsystem (BSS). There is one Mobile Switching Centre controlling the functioning of many BSS. Different MSCs are connected to provide service coverage in a large area. Contrary to this Internet consist of connection of computer LANs. Most of these computers, in Internet infrastructure are non-portable. But due to collection of large number of high speed computer, Internet infrastructure provides faster communication and processing speed. So, ubiquitous computing infrastructure devices may be arranged to form hexagonal cells with minimal proximity range to enhance battery life of user's mobile device.

This paper is organized into four sections. Section 2 presents Adaptation of Middleware Layer for Mobility Support. Section 3 introduces Power Consumption in Cellular System. In section 4 details of experimental setup with results is given. Section 5 concludes this paper.

2. Adaptation of Middleware Layer for Mobility Support

On the basis of utility of ubiquitous computing environment to its users, it may be divided in three sections as mentioned below-

- Service Infrastructure
- User Mobility
- Ubiquitous Computing Infrastructure Scenario

2.1 Service Infrastructure

The complete area of user mobility is to be covered by infrastructure devices. So this area has to be divided into different sections called active areas. All the devices in any particular active area are considered to be connected in wired or wireless LAN forming a distributed system of services with the help of middleware layer. Middleware layer makes services on these devices platform independent and transparent, which are essential attributes of distributed applications.

2.2 User Mobility

Users in ubiquitous computing environment may move freely from one place to another. Sufficient number of ubiquitous system devices along path of movement provides service without any break. Unique identification technique like RFID [2][3] may help to automatically detect user device and process without any explicit network setting.

2.2.1 Internet Infrastructure

Internet is a world wide connection of computers on basis of client server architecture, connected through a series of proxy servers called Internet Service Provider (ISPs). Internet forms a hierarchical connection of LANs. If a computing device moves from one LAN to another, then need to acquire new IP address. However Internet may provide connection between any two computers, but they have to be bound to a LAN to access any services [4].

2.2.2 Cellular System

A cellular system has been designed to support mobility of users' mobile phones, also called Mobile Stations (MS). In a cellular system the complete area of coverage is divided into various hexagonal cells each managed by a Base Station Subsystem (BSS). Many BSCs are further connected to a Mobile Switching Centre (MSC). Unique identification of MS does not change with movement from one MSC to another and MS need not re-establish the identity in new BSS. Cellular systems provide very good provision for subscriber mobility but it does not provide the same type of service access as Internet infrastructure.

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2.3 Ubiquitous Computing Infrastructure

Basic requirements of ubiquitous computing system may be fulfilled by combining the features of Internet and cellular system. Computing devices may be arranged in the form of cells (coverage area of one BSS), with each cell having one transceiver to cover the user devices in the cell. These cells (Fig1) may be called Active Areas (AA) in ubiquitous system. For mobility support each user device must have a consistent global unique identification, which does not change when user moves from one LAN/ BSS/ AA to another

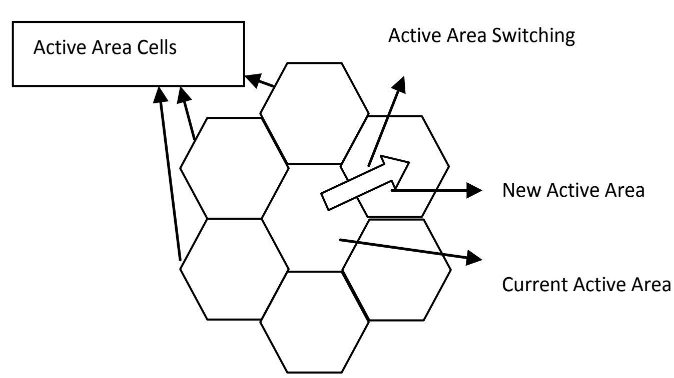

Fig 1: Cell cluster to support user mobility

All the user's devices have unique identification tags like RFID to track their location. Whenever a user device is detected in an active area other than its home, it will be identified by its unique identification tag.

3. Power Consumption in Cellular System

Cellular system provides a very good support and coverage for mobility of users. Users in ubiquitous computing scenario have mobile battery operated devices. So communication system in ubiquitous computing should be energy efficient to sustain battery power for long time. Cell size plays an important role in this context. Power required to transmit a signal between user mobile and base station transceiver is increases with increase in distance between mobile device and base station transceiver. Power of the signal generated by transceiver of base station and mobile station will be same throughout a given cell as exact distance between base station and mobile user can not be determined. So, the power of signal for proper communication is dependent on the radius of cell as mention below [8]

$$Esignal = Eref * d^{i}$$

where

Esignal is average signal power required to successfully transmit signal from mobile device to base station transceiver and vice versa.

Eref is signal power required to transmit signal over one unit of distance (e.g. 1m)

d is maximum distance between base station transceiver and user's mobile device transceiver i.e. radius (R) of the cell in a cellular system.

i Value of 'n' depends on environmental factors, like medium of transmission, level of noise. In noise free environment value of 'n' is '2'.

So, power consumption per unit of data transfer is higher in a cellular system with larger size of cells. In other words a signal with higher power/amplitude will travel larger distance. Consequently there is a tradeoff between area covered by a transceiver and rate of power dissipation of batteries of mobile devices covered in that area

4. Experimental Setup and Results

To establish this fact a simulation setup for energy consumption behavior is created. To reduce the size of cell, low power transceiver need to be used. Case study of two wireless transceivers with 10m radius of coverage and another with 1000m radius of coverage have been simulated. For effective comparison, similar values of parameters for both stations have been assumed. Only coverage distance varies. Both base stations are assumed to provide connection to 250 wireless devices. Energy requirement while transmitting or receiving k-bit message over a distance d may be expressed as below [7]

Transmitting

$$E_{Tx}(k, d) = E_{Tx\text{-}elec}(k) + E_{Tx\text{-}amp}(k, d)$$

$$E_{Tx}(k, d) = E_{elec} * k + E_{amp} * k * d^{2}$$

Receiving

$$E_{Rx}(k) = E_{Rx\text{-}elec}(k) = k * E_{elec}$$

Where

$E_{Tx\text{-}elec}$ - energy dissipated per bit at transmitter

$E_{Rx\text{-}elec}$ - energy dissipated per bit at receiver

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E_{amp} - amplification factor

E_{elec} - cost of circuit energy when transmitting or receiving one bit of data

E_{amp} - amplifier coefficient

k - a number of transmitted data bits

d - distance between a user mobile device and base station transceiver

Parameters values used for simulation are as shown below

Parameter	Quantity
Total number of nodes, (N)	250
Initial energy of each node (Joules), *Ein(n)*	200
Packet size (*k*) in bytes	100
Eelec in nano Joule per byte	50
Eamp in pico Joule per bit	100
Radius of coverage (d_1) of first Base Station(m)	10
Radius of coverage (d_1) of second base station(m)	1000
No. of transmission & receiving rounds simulated	400

In simulation, every device transmits and receives 100 Byte packets up to a maximum of 400 times.

- Simulation result for cell size of 10m radius

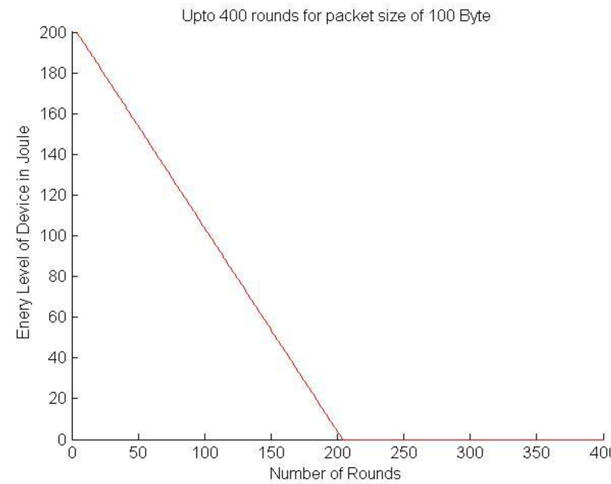

Fig 2. Energy consumption rate in cell size of 10m

So, a device transmits on average 200x100 bytes (Fig2.) of data before its energy level drops below minimum level. A device complets more than 200 rounds of transmission over a distance of 10m.

- Simulation result for cell size of 1000m radius

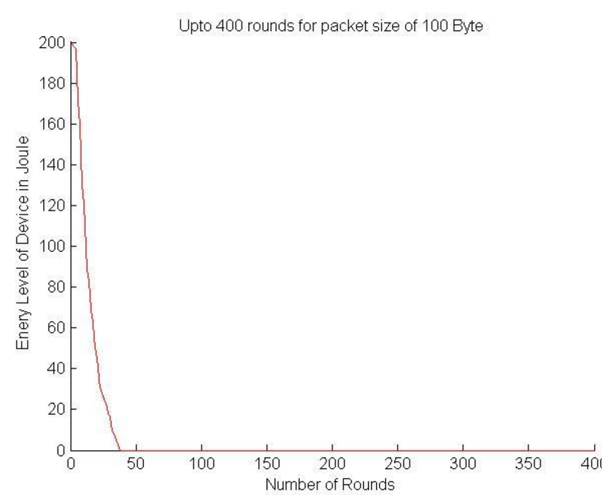

Fig 3. Energy consumption rate in cell size of 1000m

So, a device transmits less than 50x100 bytes of data before its energy level drops below minimum level. So, number of communication rounds drops to less than 50 from 200, if distance between transceivers mobile device and base station is increased from 10m to 1000m (i.e. 1Km). Transceivers with range varying

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from 10m in case of Bluetooth, to 10 Km in case 3G networks are available [9]. To optimize the energy utilization of ubiquitous mobile devices, cell size need to be reduced to minimum level possible. To effectively implement concept of ubiquitous computing a device has to be provided with service access in its closest proximity where it may use infrastructure devices like display panel. Bluetooth transceivers of 1m, 10m, and 100m range are available commercially [10].

5. Conclusion

By increasing power or amplitude of signal generated, its range may increase. However hardware cost of low range transceivers is less as compared to long range transceiver. Apart from improving battery life of users' mobile devices, low range transceiver also insures more precise prediction about location of a user. For example, Bluetooth transceiver with 1m range can detect a user location with a precision of 2m (i.e diameter of cell). With improvement of precision in location detection, implementation of context based services, like display of user data on closest infrastructure panel, becomes feasible.

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