Future Scintillation of Ubiquitous Computing

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Abstract

Ubiquitous Computing can be considered as the future computing paradigm that can provide unparalleled level of convenience and productivity to the world. Ubiquitous computing is making many computing devices available throughout the physical environment to facilitate seamless interaction with the surroundings and available resources by making these computing devices invisible to the user. The main objective of this paper is to explore the current status of ubiquitous computing and describe various research projects as well as proposed ideas by different scientists on ubiquitous computing. In the last section of this paper an attempt is made to explore the future utilizations of ubiquitous computing in multiple fields.

Keywords – ***Ubiquitous Computing, Context Awareness, Microbial Forensics, Bioterrorism, Logistics, VANET, Area Mobility***

1. INTRODUCTION

Ubiquitous means being every where at the same time – omnipresent. Ubiquitous computing is third wave of computing after mainframe computing and PC computing introduced by Mark Weiser [1] in 1988 at Xerox's Palo Alto Research Center (Parc). He is often referred as the father of ubiquitous computing. He coined the term to describe a future in which invisible computers, embedded in everyday objects, replace PCs. Large number of tiny, wirelessly intercommunicating microprocessors [2], which can be more or less invisibly embedded into objects. These mini-computers having sensors can record the environment of the object in which they are embedded and provide it with information processing and communication capabilities. A new, additional quality such objects have is that they know where they are, which other things are in the vicinity and what happened to them in the past and acts accordingly. These normal objects then become Smart Objects. The concept of ubiquitous computing is making many computing devices available throughout the physical environment to facilitate seamless interaction with the surroundings and available resources by making these computing devices invisible to the user. Applications need to adapt according to the user's environment and uncertainties. Ubiquitous computing (Ubicomp) is networked

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microprocessors embedded in everyday objects not just mobile phones and home appliances but also pen, books, bookshelves, bus stops and vehicles--all talking (**Fig. 1**) to each other over some form of links. In ubiquitous environment service depends on location, capabilities of communication terminal, user status. For secure communication environment A6 which are Anytime, Anywhere, Any network, Anyone, Any organization has to be accomplished. Invisibility, Non-Intrusiveness, Context awareness, Mobility, Adaptability, extended computing boundaries are the features of ubiquitous computing.

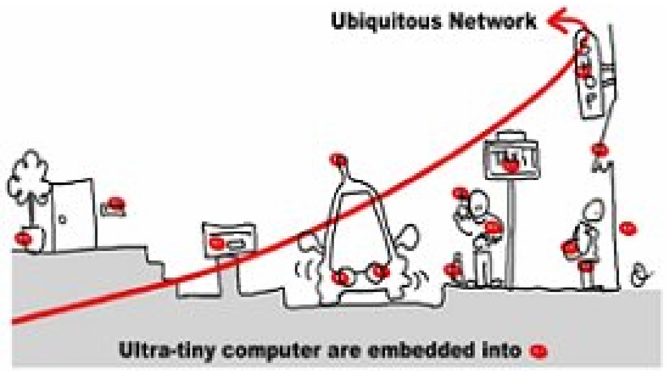

Fig. 1
Source: rainbow.i3s.unice.fr

Providing security in ubiquitous environment is a major issue & a challenge. User don't know in order to service his request what network he is accessing, what is going on in the background, as in ubicomp environment computing runs in the background. So privacy and trust security issues arise. Security policies must be designed dynamically. These policies have to adapt according to context of the user. Security policy has to dynamically change for the same user accessing a office system during office hours in the office and outside the office. Some of the other issues related to the ubiquitous devices are power consumption, cost and user interfaces. Ubiquitous devices have to be mobile or consistently on. This means they have to operate on low power battery supplies as these devices are always on. Innovative cost effective solutions must be planned and designed for ubiquitous computing. Another issue is of innovative user interfaces for ubicomp devices so that the interaction with invisible, embedded information systems takes place naturally like by speech or physical interaction. This new interaction includes not only the automatic context capture say location but also identify the user's states or his intended actions like recognition of critical situations in medical monitoring systems.

2. CURRENT STATUS OF UBIQUITOUS COMPUTING

Today we seem to be in the early stages Ubiquitous computing but we have not yet realized this. No doubt the present form of ubiquitous computing is some what different from what Weiser's idea was. Presently we have mobile devices like cell phones, Personal Digital

Assistants, Laptops, etc. These are similar to Ubiquitous devices which are always at hand. Now we have always available networks like Bluetooth, GPRS, GSM, 3G, high speed LAN along with wireless technology. These always available networks can be termed as Ubiquitous networks. In terms of Ubiquitous services currently most of the services are location based.

Present Ubiquitous computing is defined as state [4] where mobile devices such as iPad, cloud computing applications like Google Docs and high speed wireless networks 3G or large area Wi-Fi combine to eliminate the computer as the central medium for accessing digital services. In the last six months, thanks to a number of seemingly unrelated innovations, that revolution has arrived. Since June, Microsoft started advertising Windows 7's cloud capability as a selling point; Google announced a Chrome operating system that more closely resembled an Internet browser than a traditional OS. Apple's iPhone [3] is a great example of the beginning stages of ubiquitous computing. The user interface is much more intuitive compared to other smart phones previously introduced and currently in the market. It has been a huge success and shows that people want technology that is simpler to use. Industry analyst IDC predicted that in 2011, mobile device sales will overtake computer sales.

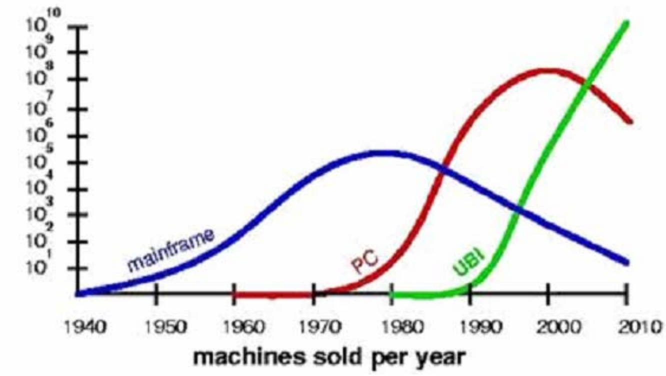

Fig. 2
Source: https://webspace.utexas.edu/chouyp1/ubicomp/ubicomp.htm

For years [4], incremental advances in academic labs moved technology closer to ubiquitous computing. But in the last few months, the commercial infrastructure needed to enable the leap arrived. Taken together, these concrete advances signal that the main barriers preventing the jump from the "PC era" to the "ubiquitous computing era" have finally fallen. As we enter 2011, the age of ubiquitous computing is upon us.

Fig. 3 shows three major eras of computing. Each of these eras represents a major difference in the role computers play in human life and society. The three eras also correspond to major shifts in the dominant form of computing devices and software. This is a conceptual timeline, not a graph of any actual data. The y-axis was intended to be something like overall impacting of computing upon average individuals but can also be seen as an abstraction of other relevant factors such as economic impact. The first era [5] was Mainframe Computing

Era which started with the earliest days of computing in the 1950's and obviously Mainframe computing still is and will continue to be an important sector of computing. It was focused on using computers to enhance and empower large organizations such as commercial enterprises and governments. Its applications were largely about collecting and processing large amounts of schematized data.

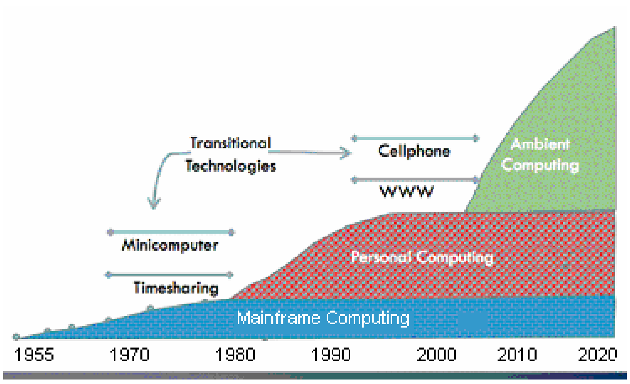

Fig. 3
Source:http://www.istockanalyst.com/finance/story/5033251/avoiding-losers-in-the-3rd-era-of-computing

Around 1980 the primary focus of computing started to rapidly shift towards enhancing and empowering individuals computing. This was the beginning of the Personal Computing Era. Its applications were largely task centric and focused on enabling individuals to create, display, manipulate, and communicate relatively unstructured information. We are currently in the early days of the third era of computing. This new era of computing is about using computers to augment the environment within which humans live and work. It will be an era of smart devices, perpetual connectivity, ubiquitous information access, and computer augmented human intelligence. There is not yet a universally accepted name for this new era. Some call it post-PC, pervasive, or ubiquitous computing. Others who focus on specific technical aspects of the new era call it cloud, mobile, or web computing. The term that currently prefer for now is "ambient computing". In the Ambient Computing Era humans live in a rich environment of communicating computing devices and a ubiquitous cloud of computer mediated information. In the Ambient Computing Era mainframe computing and task-oriented personal computing style applications will still be used but the main characteristic of this era will be the fact that computing is shaping the actual environment within we live and work.

3. RESEARCH PROJECTS AND PROPOSED IDEAS OF SCIENTISTS

For ubiquitous computing to reach to the present stage contribution of various research projects which provides different prototypes cannot be ignored. Many scientists proposed their ideas regarding different utilizations of ubiquitous computing in various fields. Few of these projects and proposed ideas are

3.1 Active Badge, Bat

Active Badge System of Want et al. was developed by Olivetti Research Labs, University of Cambridge, UK, 1989-92 for Locating people (and devices) with Room level accuracy [6]. It locates the people inside the building and accordingly transfers their calls on respective extension numbers. This was perhaps the first context-aware computing application, designed to enhance user mobility and to support location-awareness. It was intended to be an aid for a telephone receptionist before mobile phone networks became widespread so that employees could be contacted when they were away from their desk or home location. Once a person was located, phone calls could be forwarded to a desk-phone closest to where the person was located. An Active Badge periodically sends infrared signals to sensors embedded in rooms throughout the building. The location determination accuracy of the Active Badge system was limited to identifying which room a person was in. In 1995, Ward et al. (1997) developed a new active tag system, called the Active Bat, based on ultrasound4 that could locate people up to an accuracy of 3 cm. The system used a base station to ask the Bat for a signal that is then measured in multiple ceiling receivers, the position being determined using trilateration. (Lateration and Angulation are often usefully combined in order to know not only where an object is but from which orientation it is being viewed.)

3.2 ParcTab

Active Badge System became the forerunner that led to the development of the ParcTab [6] at PARC. The ParcTab system consisted of palm-sized mobile computers that could communicate wirelessly through infrared transceivers to workstation-based applications. The ParcTab was designed for portability and could also be carried or worn, e.g., clipped on a belt. It was intended to promote on-demand computing, constant connectivity and supported location-awareness. All pad, tab, and badge prototypes were fully functional and used in everyday use by PARC experimenters. At its peak in 1994, about 40 lab members at PARC used ParcTabs during their daily activities. The aim of the LiveBoard was to support collaborative group design and work. It later became a commercial product.

3.3 Smart Floor

Smart floor [7] developed by Robert J. Orr and Gregory D. Abowd at Georgia tech (1997), is a piece of flooring which tracks and uses information about the force of a persons foot steps. By looking at previous footstep samples, a computer programming running in the background could identify the person walking on the smart floor with 93% accuracy. Because a user never has to think about directly interacting with any interface, the smart floor is an unobtrusive method for user verification. Thus, it fits well into the ubiquitous idea.

3.4 Lancaster's Guide System

The research team at Lancaster designed the Guide system [8] to provide visitors to the city of Lancaster with the type of information normally found in a tour guide, but contextualized on the basis of the visitor's interest and movement around the city. They based the system on a distributed, dynamic information model, augmenting standard hypertext with geographic information and navigation elements, as well as context-sensitive active components. Users interact with the system using tablet PCs as end-systems, connected to information servers through an 802.11 network deployed around the historic city's major attractions. This network covers most but not all of the inner city. Its cell structure also provides end-systems with coarse grained (approximately 200 m accuracy) location information based on their current cell identifier. In 1999, the Lancaster team deployed Guide and evaluated it in a field trial for approximately four weeks. Sixty tourists visiting Lancaster used the system—people of all age groups, mostly without any previous experience with information navigation systems such as the Web.

3.5 MediaCup

The MediaCup [9] project at the University of Karlsruhe is an experiment with the idea of augmenting everyday objects with a digital presence while preserving their original appearance, purpose, and use. The first objects prototyped were coffee cups equipped with a low-power microcontroller, embedded sensors, and wireless communications (**Fig. 4**). The embedded technology lets the cups sense their physical state and map sensor readings autonomously to a domain-specific model of the cup. This object model is broadcasted at regular intervals over the wireless link to establish the object's digital presence. Karlsruhe first deployed the augmented coffee cups in September 1999 in an office environment. Since then, few cups are mostly used occasionally by lab members and visitors. The MediaCup deployment is a long-term experiment aimed at understanding opportunities that might arise from the digital presence of objects.

Fig. 4
Source: http://ubicomp.teco.edu/hardware

As the project evolves, applications that use MediaCup information has emerged. An initial application simply visualized cups and their state on a 2D map of the office environment. This was followed by more embedded applications such as door plates that used the aggregation of hot cups in a room to infer and indicate meetings, and wrist-worn PCs that issue warnings if the user picks up a cup with coffee or tea that's still too hot to drink.

3.6 Radar

P. Bahl and V. Padmanabhan proposed a radio-frequency based system in the year 2000 for locating and tracking users inside buildings. RADAR [10] operates by recording and processing signal strength information at multiple base stations positioned to provide overlapping coverage in the area of interest. It combines empirical measurements with signal propagation modeling to determine user location and thereby enable location-aware services and applications.

3.7 Passenger Support System

A Passenger Support System [11] was proposed in 2002 by K GOTO and Kambayashi to help old and handicapped users in railway stations. User employs mobile devices to access central database for creating a travel plan. The central system offers several alternative plans, users selects a plan and reserves tickets. During the travel, the mobile device queries local and central databases to get travel info and schedules. **Fig. 5** shows Central database that has general use data, fewer details that supports travel planning whereas local database has more details like local station map, platform info and Mobile traveling requires handoff (devices like Cell Phones, PDA) between base stations and mobiles.

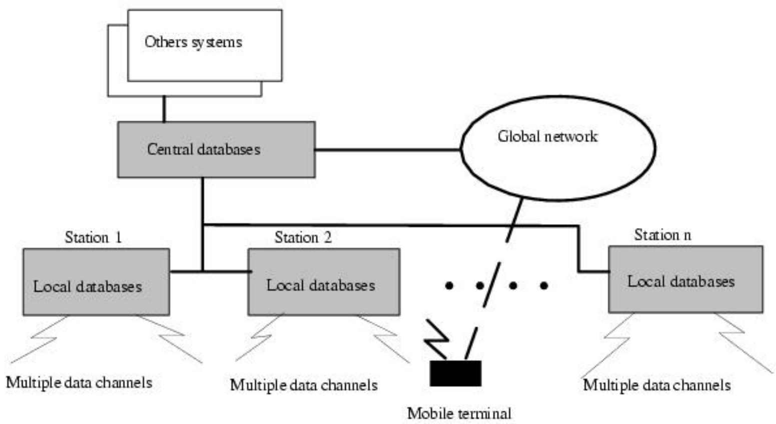

Fig. 5

The basic configuration of the system to support handicapped passengers and it can make public transport a system friendly to use is shown in **Fig. 6**. Old and handicapped people need special devices so RF ID tags are buried in the center of walkways on the station floor which are connected with antenna and receiver to cane. The mobile terminal can read location data through a cane in which a small reader is installed. System get location information from the RF-ID tags and other information from a radio communication channel. Mobile terminal communicates with the center server via telephone network too. All operations of the mobile terminal can be done by voice and messages are given by voice too.

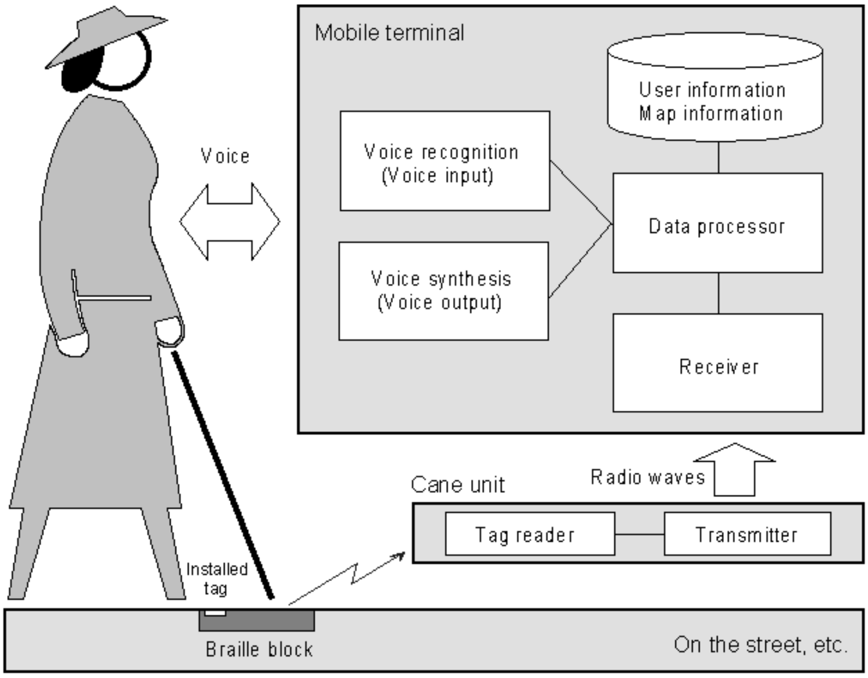

Fig. 6

When the mobile terminal gets a location datum from a data carrier, it generates a message about the current situation by mapping the location datum with the station map. There is possibility to repeat the message by saying ’repeat’ incase user misses a message. Hence visually handicapped passengers can know where they are now and which direction they should go by using the mobile terminal.

3.8 SenSay : Context Aware Mobile Phone

Daniel Siewiorek [12] et al at Human Computer Interaction Institute and Institute for Complex Engineered Systems of Carnegie Mellon University, USA (2003) developed a prototype of context aware Mobile Phone named SenSay which adopts dynamically its behavior based on its user's state and surroundings. Sensing and Saying (SenSay) mobile phone provides the remote caller information on the current context of the phone user with the help of light, motion, and microphone sensors. Sensors are mounted at various parts of the body with a central hub, called the sensor box, mounted on the waist provide data about the user’s context. This phone uses five functional modules (**Fig. 7**): the sensor box, sensor module, decision module, action module, and phone module and four states: Uninterruptible, Idle, Active, and the default state, Normal. Sensor box collects physical sensor data like noise, light, temperature, motion sensors and controller, the software based sensor module queries that data, the decision module determines the phone's state, the action module sets that state, and the phone module provides access to the mobile phone operating system and user interface. Apart from manipulating ringer volume, vibration, and phone alerts, SenSay can provide remote callers with the ability to communicate the urgency of their calls, make call suggestions to users when they are idle, and provide the caller with feedback on the current status of the Sensay user.

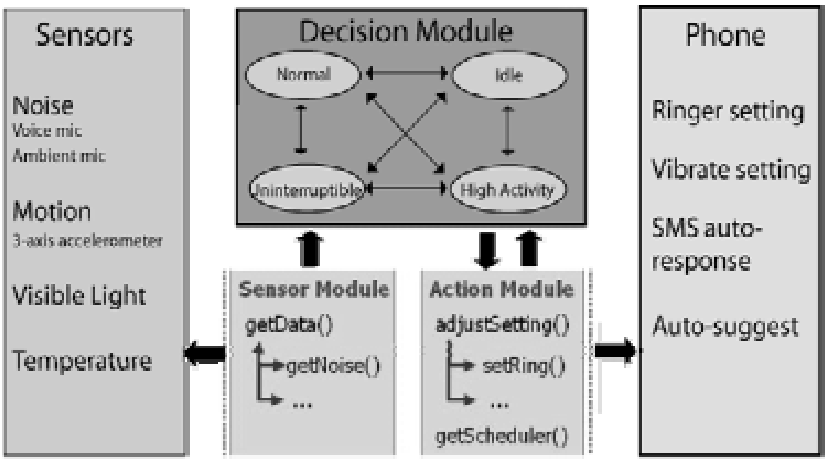

Fig. 7

3.9 GETA Sandals

At the 2005 UbiComp in Tokyo Japan, a demo was given for a device called GETA Sandals [13]. These sandals are used as a means to obtain positioning information with out very much infrastructure. Unlike other positioning systems, they do not require wi-fi points or ultrasound to aid in determining their location. They keep track of their own position by calculating the displacement vectors of each foot through sensors which are placed inside each sandal. These vectors are added up, and from these summations, distance and position can be determined.

3.10 SPARK: Smart Parking Scheme for Large Parking Lots

Rongxing Lu et al in 2009 proposed a smart parking scheme based on vehicle ad hoc networks (VANET) for large parking lots. Major car manufactories and telecommunication industries gear up to equip each car with the On Board Unit (OBU) communication device, which allows different cars to communicate with each other as well as roadside infrastructure, Roadside Units (RSUs) to improve not only road safety but also better driving experience. SPARK [14] scheme can provide real-time parking navigation service to drivers in large parking lots to find the vacant parking space quickly. Hence fuel and time wasted in search of vacant parking space can be reduced. Also this scheme provides VANET based intelligent anti-theft protection service. All vehicles parked at the smart parking lot are guarded by the parking lot's RSUs. Once a vehicle is illegally leaving the parking lot, the RSUs can quickly detect the anomaly. The proposed system model consists of a trusted authority (TA),OBUs equipped on the vehicles, stationary parking lot RSUs and a large number of parking spaces. TA is a trust and powerful entity, who is in charge of the registration of both OBUs and the parking lot RSUs. OBUs are installed on the vehicles, which can communicate with each other and RSUs for achieving information like traffic information and parking lot information. Each OBU has a unique identifier ID*i*. To protect the privacy of the OBU, when an OBU with ID*i* registers itself to TA, TA first converts the real identifier ID*i* into a pseudo-ID PID_i, and generates a private key *ski* corresponding to the pseudo-ID of the OBU. When an OBU enters a smart parking lot, it will receive a pair of ticket ID and respective ticket key, which is only known to the driver.

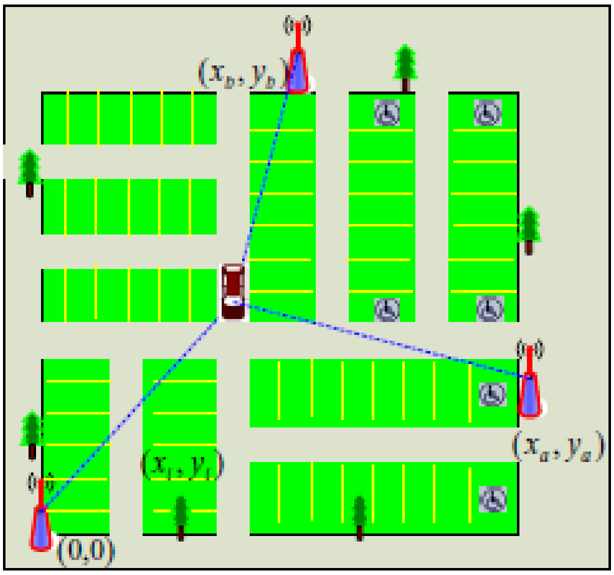

Fig. 8

Fig. 8 shows three RSUs,: RSU_0 at position (0, 0), RSUa at position (x_a, y_a) and RSU_b at position (x_b, y_b), are erected in the parking lot. With this deployment, the whole parking lot can be under surveillance of the three RSUs. After the smart parking lot with identifier ID*j* is inspected by TA, TA will generate a private key *skj* corresponding to the identifier ID*j* and distribute the private key skj to these parking lot RSUs. **Fig. 9** shows one placement of RSUs in a smart parking lot, where the distance between RSU_a and RSU_b is w, the transmission ranges of RSU_a, RSU_b and RSU_0 are r, r and $r_0 = \sqrt{r^2 - (w/2)^2} + w$, respectively. Then, the size of the overlapped surveillance region is

$S = 2r^2 . \arccos(w/2r) - w \,.\, \sqrt{r^2 - (w/2)^2}$

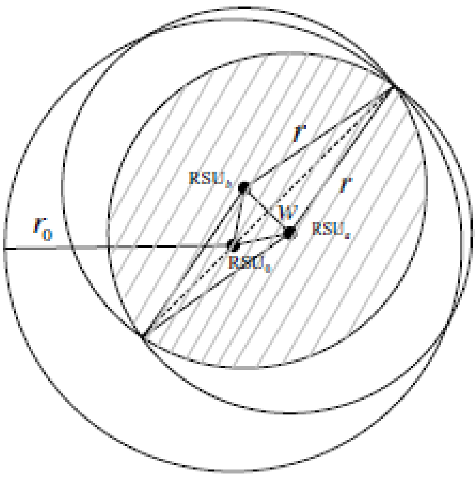

Fig. 9

Algorithm: Position Vehicle

Data: distances (d_0, d_a, d_b) measured by (RSU_0, RSU_a, RSU_b), the height h of RSUs and a threshold value ε that is contingent upon the noise in the ranging measurement.

Result: Vehicle's current position (x_v, y_v).

Begin

Convert (d_0, d_a, d_b) to the plane distances (D_0, D_a, D_b), where

$$D_0 = \sqrt{d_0^2 - h^2}, D_a = \sqrt{d_a^2 - h^2}, D_b = \sqrt{d_b^2 - h^2} \quad (2)$$

Solve out two possible positions (x_{v1}, y_{v1}) and (x_{v2}, y_{v2}) from

$$\begin{cases} \sqrt{(x - x_a)^2 + (y - y_a)^2} = D_a \\ \sqrt{(x - x_b)^2 + (y - y_b)^2} = D_b \end{cases} \quad (3)$$

if $|\sqrt{x_{v1}^2 + y_{v1}^2} - D_0| \leq \varepsilon$ **then**

| **return** (x_{v1}, y_{v1})

else if $|\sqrt{x_{v2}^2 + y_{v2}^2} - D_0| \leq \varepsilon$ **then**

| **return** (x_{v2}, y_{v2})

end

End

3.11 Pollution Monitoring and Evaluation System

A project was initiated at IIM Kolkata on Pollution Monitoring and Evaluation system [15] which uses Sensor based Wireless Mesh Network for the protection of Public spaces. The objective of the project is development of a Wireless Sensor Network for pollution monitoring by identifying the primary source of emission, (detecting Benzene, Toluene, Xylene, CO & CO2 et al, developing a mechanism for data filtering and aggregation, power management and finally commercialization of the product/ system. The field trials have been successfully completed in Kolkata Metropolitan area and the project is to be launched soon.

3.12 Wireless Sensor Network for Real-Time Landslide Monitoring

Amrita University, Kollam, Kerala is working on a project based on Wireless Sensor Network for Real-Time Landslide monitoring [15].The project aims at development of a Wireless Sensor Network for Real-Time Landslide Monitoring with pore water pressure, tilt meter and rain gauge sensors, along with a wireless sensor network for the deployment site. With this technology in operation, the risk of landslide will be assessed and remote command and control interface will be provided for different purposes. The on-site sensors are to be installed very soon.

4. FUTURE AREAS OF UBIQUITOUS COMPUTING

In future ubiquitous computing can do wonders in the various areas to provide us with an unparalleled level of convenience and productivity. Some of these areas are:

4.1 Ubiquitous Computing in Microbial Forensics and Bioterrorism

Microorganisms [16] are present in air, soil, water, and all kinds of living creatures. Many of microbes have been linked to diseases of humans, animals, and plants. Advances in molecular biology, electronics, nanotechnology, computer sciences, and information technology have made it possible to create ubiquitous devices and biosensors that would indicate presence of microbial agents in water, foods, air, hospitals, animal farms, and other environments. Analyses of microbial genomes and phylogenies have become increasingly important in the tracking and investigation of events leading to spread of microbial diseases and biocrimes. With the help of Ubiquitous computing it appears possible to develop biosensors that could detect the presence of biocrime/ bioterror agents in diverse environments. Microbial forensics has become an important field for research and development due to increased threats of biocrimes. Microbial forensics requires utilization of diverse data that are acquired through standard processes in distributed locations. Technologies for data production are evolving rapidly, especially with respect to instrumentation and techniques that produce high-resolution data about the molecular constituents of living cells (DNA, mRNA, proteins, and metabolites) that are used as microbial signatures/fingerprints.

4.2 Smart Homes

In the present fast life where nuclear families concept has replaced joint families concept, home care of elders, children and even protection your house are some of the issues which bothers all of us when we are away from home. Smart home concept is a promising and cost-effective way of improving home care for the elders and children in a non-obtrusive way, allowing greater independence, maintaining good health and preventing social isolation. In these smart homes, ubiquitous devices are implemented every where and they automatically communicate with each other. Then in future you don’t have to switch on the light or say AC when you entered the room. These things will automatically switched ON or OFF as you enter or leave the room.

4.3 Future Healthcare

The healthcare applications provide a better quality of care with the use of ubiquitous computing. Instead of hospitalization, patients and elders can be assisted in their own environment 24x7 with numerous smart devices equipped with sensors, actuators, and biomedical monitors which improve the possibilities for medical care and support independent living. These devices operate in a network connected to a remote centre for data collection and processing. Vital parameters and data of the patients are recorded along with monitoring the home environment. The remote centre diagnoses the situation and initiates assistance as required. In case of emergency an alarm may be ring. Think of the future where you don't have to remember the due dates of vaccinations of your children.

4.4 Future Logistics

In logistics [2] it is important to know where the goods are at any time. In the long term ubiquitous computing furthers this goal, in that transport objects are equipped with communication and computing capabilities. For a more efficient flow of goods and information from suppliers to enterprises, containers, pallets and products will be universally equipped in the mid term with RFID transponders, which improve traceability and transparency in the supply chain. Thus the logistics processes can be optimized from the process planning and steering up to the handling of goods and information flows. This helps in stopping black marketing & controlling pricing.

4.5 Area Mobility and Traveling

Ubiquitous computing can be a great help in the area mobility and traveling. It will be the basis for a new generation of strongly networked and integrated systems to control transport flows and to inform road-users about the traffic, nature and type of road ahead. The time will come when you drive on a road, road sensor automatically interact with your vehicle to inform the driver about the near by filing station, restaurant or a particular diversion.

4.6 Banking

Cash withdrawal and other facilities are provided 24 x7 by banks with ATM machines. ATM's are now popular because of anytime, any ATM, anywhere concept of cash withdrawal. With heavy load on ATM's as every one is using them, they require a continuous watch for insufficient amount of cash. But the banks currently don't have this information so they put the cash in ATM's according to their convenience and schedule. Also security of

ATM's is a new challenge with the increase in cases of ATM thefts. In future with the help of ubiquitous computing ATM can sent a message to the branch about less cash left in the machine. If unauthorized persons try to open the ATM, then an alarm can be set off in the police station as well as the branch of the bank.

4.7 Business

Every business needs to know the updated position of their inventory as many decision's like when to order, how much order affects the business. An automatic inventory service can be implemented if every part in a warehouse sends a notification to the warehouse management system if it enters or leaves the warehouse. Warehouse management system not only informs about the under stock or over stock items but can also be a good tool to find the items.

5. CONCLUSION

Ubiquitous Computing can be the future era of computing. Ubiquitous computing is currently successful as an emerging area of research to provide prototypes for the proposed ideas of various scientists. Prototypes are easy to make but we have to wait for the actual moment when this computing becomes a reality. Some of the technologies for making it a reality are existing and for some, we have to wait. A considerable infrastructure would have to be implemented before this vision could become a reality. We have to get the answers of questions like security of the devices, how much freedom should be given, who and how the UbiComp environment will be controlled?

References

[1] M. Weiser R. Gold and J. S. Brown, "The origins of ubiquitous computing research at PARC in the late 1980s" in the IBM system Journal Volume 38, 1999 p- 693-696.

[2] Friedewald Michael et al, Ubiquitous Computing TAB report no. 131. Berlin 2009, 300 pages

[3] https://webspace.utexas.edu/chouyp1/ubicomp/ubicomp.htm

[4] In the Future, Computing is (Cunningly) Constant by StuartFox, Innovation News Daily Assistant Editor, 14 February 2011

[5] Allen Wirfs-Brock,: "The Third Era of Computing", Thoughts and Things, January 23, 2011 in Post-PC/Ambient Computing

[6] Ubiquitous Computing: Smart Devices, Environments and Interactions Stefan Poslad © 2009 John Wiley & Sons, Ltd. ISBN: 978-0-470-03560-3, page no 42-43

[7] Daniel Schomburg, “Ubiquitous Computing: Thinking About a new wave of Computing”, Computer Human Interaction Course, Clemson University

[8] N. Davies et al., “Caches in the Air: Disseminating Information in the Guide System,” Proc. 2nd IEEE Workshop Mobile Computing Systems and Applications (WMCSA 99), IEEE Press, Piscataway, N.J., 1999, pp. 11–19.

[9] M. Beigl, H.W. Gellersen, and A. Schmidt, “Mediacups: Experience with Design and Use of Computer-Augmented Everyday Objects,” Computer Networks, vol. 35, no. 4, Mar. 2001, pp. 401–409.

[10] P. Bahl and V. Padmanabhan,”RADAR: An In-Building RF-based User Location and Tracking System”, In Proc. of the IEEE INFOCOM 2000, pages 775-784, March, 2000.

[11] Koichi GOTO, Yahiko Kambayashi, “A New Passenger Support System for Public Transport using Mobile Database Access”, Proceedings of the 28th VLDB Conference, Hong Kong, China, 2002

[12] Daniel Siewiorek et al, “SenSay: A context-aware mobile phone”, Online at http://www-2.cs.cmu.edu/ aura/publications.html, submitted to the Inter-national Symposium on Wearble Computers, 2003.

[13] Kenji Okuda, Shun-yuan Yeh, Keng-hao Chang, Chon-in Wu, Okuda Kenji, Hao-hua Chu, Geta Sandals: Knowing Where You Walk To. UbiComp 2005

[14] Rongxing Lu, Xiaodong Lin, Haojin Zhu, and Xuemin (Sherman) Shen ,“SPARK: A New VANET-based Smart Parking Scheme for Large Parking Lots” for publication in the IEEE INFOCOM 2009 proceedings.

[15] http://www.mit.gov.in/content/ubiquitous-computing-projects,last accessed 17 September, 2011.

[16] Gaya Prasad, Minakshi: “Ubiquitous Computing for Microbial Forensics and Bioterrorism” published in Ubiquitous and Pervasive Computing: Concepts, Methodologies, Tools, and Applications, by Judith Symonds Auckland University of Technology, New Zealand, Vol II page no. 957-972