The Integration of Wireless, Wired Access and Embedded Agents in Intelligent Buildings

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Abstract

This paper presents many different challenges related to Intelligent-Building (IB) communication. The purpose of this research is to determine the best network architecture for IB by the integration of mobile intelligent agents, wireless and wired networks. IBs need to be adaptable to the demands of people using them. For this reason it is necessary to provide an open network architecture with free conversion between protocols and high-speed communication. This paper justifies the use of open technologies such as the Universal Mobile Telecommunications System (UMTS), Internet Protocol version 6 (IPv6) and open platforms such as CORBA and Jini. In addition it considers wireless technologies such as Bluetooth, Wireless 802.11, etc. The paper concludes by presenting a combination of UMTS and IPv6 mobile environments as possible solutions to the needs of Intelligent-Building.

1. Introduction

The focus of this paper is a proposal for a new network architecture for Intelligent Buildings (IB) which integrates mobile intelligent agents, wireless and wired access networks. An Intelligent-Building has been defined as "one that utilises computer technology to autonomously govern the building services environment so as to optimise user comfort, energy-consumption, safety and work efficiency". [Callaghan, 2000a]

From the telecommunication point of view it is very important for IBs to consider communication between intelligent autonomous systems, intelligent personal devices, management information systems, mobiles, etc. In addition it needs to support communication between different Intelligent Buildings. Section 2 explains the network architecture model for IBs, which seeks to achieve the best form of communication both internally within an IB and externally between IBs.

Full integration of IBs with telecommunication systems is becoming increasingly important, for example to facilitate more efficient commercial transactions. With the Internet emerging as the best communications platform, traditional isolated design tools will probably not survive. For this reason, wired and wireless technologies are presented in this paper as providing suitable communication for IBs. In section 2.1 we explain why UMTS and IPv6 mobile were chosen as the environments to provide the network access.

Section 2.2 considers open platforms such as CORBA and Jini whilst section 3 explains the network management that has to be applied in this context. Section 4 describes the research challenges faced together with our communication architectural solution and finally, section 5 gives our closing thoughts.

2. Network architecture in Intelligent Buildings

The application of UMTS and IPv6 to IBs is a new research area and is of considerable interest because IBs depend totally upon communication and these platforms are an excellent solution to achieve many of the IB communication needs. In this section a typical IB network is described.

An intelligent building consists of a network of room-based embedded-agents covering the entire building. An embedded-agent can be regarded as the integration of capabilities into products or machines, in an inseparable manner, that we would regard as requiring thought, if the task was done by a person [Callaghan 2000]. The physical and logical unit of an IB is a room. Each IB room contains sensors and output devices, which are monitored and controlled locally by an embedded-agent. All these embedded-agents are connected together via a network, forming a decentralised architecture that enables building-wide collaboration. This network needs, ideally, to be real-time, and to have simple but secure device interfaces comparable with the cheap nature of existing building devices such as light switches [Sharples, 1999].

IBs offer different services, for example heating, alarm systems, audio-visual units, automatic cleaning systems, etc. These services are available inside and outside of IBs via wire and wireless technologies. At the same time, IBs may offer the possibility of different communication services with shopping malls, banks, police, fire station, etc. For these reasons it is important to design an adequate communication network architecture.

In terms of the creation and maintenance of IB networks if a new device is installed in the building (e.g. a new lamp), or an existing device moved, it would be desirable that it automatically sent a signal to register with appropriate agents (e.g. lighting and energy management agents).

The IP architecture proposed in this report for IBs is based on the premise that every room (physical and logical unit of a building) has different devices connected within the room by a localised fieldbus network (e.g. Lonworks) marshalled by appropriate network management software (e.g. Jini). In addition the wider communication needs (eg inter–room/building) would be serviced by a Lan/Wan (e.g. IP) managed by appropriate software (e.g. CORBA).

The diagram [Callaghan 2000b] illustrates the different elements and connections in an IB network. The following sections explain why IPv6 mobile and UMTS were chosen for the network architecture of IB (see 2.1) and why CORBA and Jini were chosen as development platforms (see 2.2).

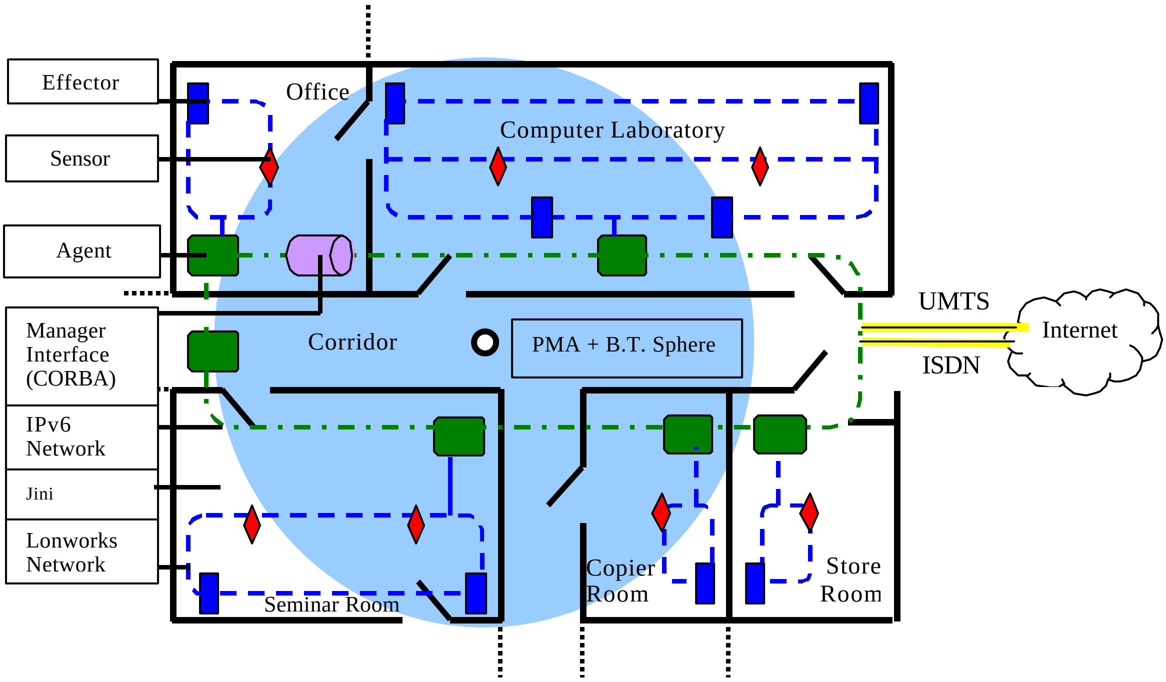

Figure 1. Building-Based Architecture [Callaghan 2000b]

2.1 Why IPv6 mobile and UMTS?

An important aspect of the potential development of IBs concerns the use of mobile personal agents that might communicate with a variety of intelligent environments amongst which the sort of IB described above will be found. Intelligent embedded-agents can help to solve some of the problems of transferring personally based data around in a complex world of intelligent environments. As you move from your home to the Mall using your car your personal agent, perhaps housed inside your mobile phone, can communicate with the intelligent environments you encounter on the way. It is argued that UMTS and IPv6 will be able to provide support for this type of mobility.

The main goal of IPv6-Mobile is to provide a transparent transfer between wired network nodes and nodes that are changing their point of attachment in the Internet. The capabilities of IPv6 mobile will be integrated in IBs and intelligent environments in general to allow users access to the devices in IB and vice versa. Mobile IP allows a mobile node to move between different subnets while retaining its own IP address and established connections. Personal mobility means that a user can change his terminal but maintain his personalised services [Atkinson 1995].

IPv6 is important to IB communication too because it allows parameters such as Quality of Service (QoS), bit rate and bit error rates (BER), vital for mobile operation, to be set by the operator or service provider.

UMTS is one of the major new Third Generation mobile systems, which has been defined by the International Telecommunications Union (ITU). UMTS seeks to build on and extend the capability of today's mobile, cordless and satellite technologies.

Mobile access to the Internet will be one of the early volume applications that will support the growth of UMTS use. Technologies such as IPv6 will be used to reduce costs and increase the performance of UMTS.

UMTS enables a new end-user proposition, which provides ubiquity and universality of services, and which can cost effectively accommodate the transition from real-time low bandwidth voice to data and real-time high bandwidth multimedia services. As terrestrial UMTS infrastructure is not expected to be able to offer services in all geographical locations, due to speed of rollout and economics, then users in such areas could be accommodated by UMTS via satellite. The UMTS network would search first for a terrestrial signal and if it is not available, it could then switch automatically to satellite [Barba, 1993].

The use of satellite systems in buildings has the disadvantage that the signal is downgraded inside the walls. One solution is to combine the satellite with pico-cell within buildings. Another disadvantage of satellite systems is that eavesdropping and active intrusion is much easier than for fixed terrestrial or mobile networks because of the broadcast nature of satellites.

IBs could use UMTS to interconnect different mobile devices, for example cars, personal watch, mobile phone, etc. IBs should be able to communicate with different organisations for example police, fire fighter, shops, etc. This communication could be ISDN (Integrated Services Digital Network) based or, where it was not possible to obtain communication with a wired network, then UMTS, with its ubiquity, could be used to establish a connection.

2.2 Why Jini and CORBA?

Jini network managment technology is based on the concept that devices should work together without low level network management or operating system issues being visible to the user.

IB networks are comprised of several devices that can be connected using Jini, for example, black goods such as TVs, VCRs, DVDs, CD players, cameras, radios; white goods such as washing machines, fridges, kettles, toasters; or brown goods such as security systems, fire alarms, HVACs, or computers and communication equipment such as PDA,s, phones, pagers and a lot of other electronic devices. Each device performs a simple task and provides services that other devices in the building may use. Jini based IB devices are flexible and able to negotiate the details of their interaction. Under Jini these devices can take charge of their own interactions, they can self-configure, self-diagnose, and self-install.

Jini is based on the Java programming language. Devices in a network employing Jini are tied together using Java Remote Method Invocation (RMI). The underlying technology and services architecture is powerful enough to build a fully distributed system on a network of workstations.

CORBA (Common Object Request Broker Architecture) defines interfaces and services to support interoperability and offers transparency to build distributed applications. The latest CORBA version takes advantage of interoperability between different manufacturer platform as hardware and software, and facilities the use of clients and servers in various languages [Web 5]. CORBA was chosen for the proposed IB network architecture because it allows each intelligent environment to have different devices, computer equipment and software systems without this heterogeneity being a problem. CORBA has others features that can be useful for IBs such as software reuse and location transparency.

The new CORBA specification [Web 5] establishes application interfaces to manage the Object Request Broker (ORB) quality policies and includes priority (e.g. end time request). The priority model of CORBA could be used to overcome the different priority schemes of the different intelligent environments.

The interoperability provided by CORBA to manage services between different systems and networks cannot be solved with Jini. CORBA and Jini are complementary, Jini is based on Java and allows a hierarchical embedded architecture compatible with CORBA. An important CORBA characteristic is that it enables standard management for network services. Also interconnection of IBs with other Intelligent Interactive Environments is easy since CORBA is an open system handling interoperability with different hardware, software and operating systems. This characteristic is very important because each intelligent environment system may have different hardware and software platforms and with CORBA it is possible to achieve the integration of different Intelligent Autonomous Systems.

3. Network Management

The difficulty of trying to interconnect and communicate among different devices, computers, agents, buildings, etc is becoming increasingly important. Managing these resources is becoming increasingly complex as networks add more components, more services, more functions and more agents.

Typically embedded-agents should report to the managing process on the status of managed network elements and receive addresses from the managing process on actions it is to perform on these elements. The managing process directs the operations of the agent. This process involves the planning, organising, monitoring, accounting and controlling of activities and resources.

Interconnection of multiple network resources and services implies interoperation of network management systems. To assure this, network management embedded-agents should use standard communication protocols. Most of the protocols used in telecommunication network management have been defined according to standard recommendations established by the ISO (International Standardisation Organisation) [Barba, 1999].

3.1 Security for IB

To realise the full potential of the integration of IPv6 and UMTS in the IBs, users must be able to trust on-line information and transactions as much as, or more than, they trust them in a building without any embedded-agents. For this reason the digital information has to be both protected and authenticated (like physical goods that are inside the building, cars, etc.). The mobile computing environment is vulnerable to passive eavesdropping, active replay attacks, and other active attacks. Third generation mobile systems can adapt to new security systems building Internet like security architecture (firewalls, virtual private networking, end-to-end encryption, etc.).

In IBs it is important to be able to identify users, because the system needs to know who is allowed access normally (e.g. owners), who is allowed access in an emergency (e.g. police, fireman, etc.) and who is not allowed access (e.g. general public).

There are several threats of possible attacks, for example problems with data confidentiality, data authenticity, service availability, signalling security and location confidentiality. One solution to this security problem is to use the IPsec protocol, which provides security by authenticating and/or encrypting transmitted data packets. [Atkinson 1995]

4. A Way Forward

4.1 A Solution

One way the above technologies can be combined is illustrated in figure 2. In this architecture, the management application built into CORBA has a Directory Enabled Network (DEN) which works as a centralized repository, coordinates information storage and retrieval thereby enabling other data and application specific repositories to be united. This DEN is used in conjunction with Jini for supervision, configuration and management of the network.

Both, wireless and wired access provide a more flexible and useful implementation strategy for users. In this approach service policy management would result in the use of Integrated Services Digital Network (ISDN) for an IB to access the Internet. If a mobile connection was necessary then UMTS could establish the connection. The service management policy we employ dictates ISDN is the first option for the system (because the wired network has better quality of service), but in cases where ISDN cannot establish a connection, then UMTS is utilised. Embedded-agents work in IBs through UMTS terminals using configurable WAP (Wireless Application Protocol) parameters by the user. IB agents' configuration can also be enabled via Internet Access.

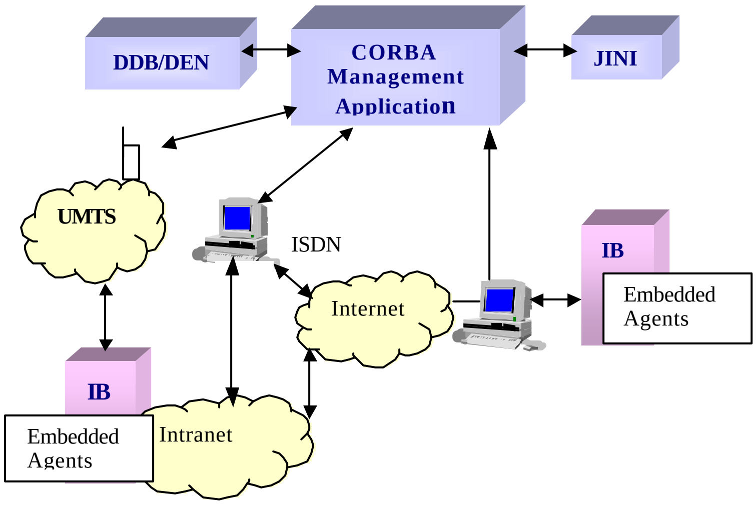

Figure 2. Proposed Multi-Mode Communications Architecture for IBs

4.2 The Research Challenges

There are several important research issues that need to be addressed in order to provide a robust and flexible IB network architecture.

One of the most important topics to be studied concerns finding the optimum architecture to facilitate integration of UMTS, IPv6, DIBAL, Jini, CORBA, DDB/DEN, and mobile intelligent agents that could form future intelligent environments. Determining the best way of connecting the different technologies is not easy because it requires integration of mobile intelligent agents (IB) with networks nodes IP/UMTS.

The new types of service that IBs will be able to offer the user (e.g. passing preferences on environmental needs to building service systems) may entail the creation of new UMTS services. These need to be formally specified and considered. In addition the security features required for intelligent buildings (and new services) need to be defined, and suitable mechanisms for implementing them found.

Finally, other significant challenges concern communication languages network management relating to the vast numbers (thousands of millions would not be an exaggeration!) of embedded-agents that will make up future intelligent environments [Cayci 99, Mintar 99].

5. Conclusion

Integration of wireless, wired and mobile intelligent agents is a very important issue in the challenge of finding suitable network architecture for IBs and Intelligent Environments.

The use of UMTS and IPv6 Mobile to provide mobile communication is important due the market strong inertia and powerful functionality that both of these technologies offer to IBs Intelligent Mobile Agents and

Intelligent Environments. Similarly, the use of Jini and CORBA offer important characteristics that can enhance the network architecture proposed in this paper.

It seems inevitable that network based products and environments will become ever more intelligent and the emergence of networks with thousands of millions of devices presents both daunting and exciting challenges to researchers in this area. More work is needed and we hope this paper stimulates interest in the increasingly important topic.

Acknowledgements: I am pleased to acknowledge the support of the Essex Intelligent Buildings group (cswww.essex.ac.uk/intelligent-buildings) with whom I spent a most enjoyable and productive period during the summer 2000. A particular thanks to Filiz Cayci and Anthony Pounds-Cornish whose help and friendship throughout my stay at Essex was much appreciated.

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