Trends and Future of Mobile Computing

Andry Rakotonirainy
andry@dstc.edu.au
CRC for Distributed Systems Technology
Level 7, General Purpose South,
The University of Queensland 4072 - Australia

Abstract

Networking homes, offices, cars and hand-held computers is the current trend of distributed mobile computing. The ever growing demand of the enterprise for integrating new technologies and new services requires a generic infrastructure. An infrastructure that allows its components to be accessed, packaged, self described, dynamically configurable, moved over wired or wireless network, deployed either in a workstation or a mobile device from anywhere at anytime. An infrastructure that can be used with new alternatives to current human-machine interfaces applicable in diverse environment.[1]

1 A scenario of the near future

Fri Sept 19 10:29:22 EST 2003 somewhere on a freeway. In a comfortable car, on a trip to a meeting at the Mercury Hotel, a voice generated by a hand-held computer named Cheetah, interrupts the 1^{st} movement of Mahler's 5^{th} symphony from the HIFI speakers and says:

> **Cheetah**: Good morning John, Good morning Jane. I have cancelled your next meeting at the Mercury Hotel due to a severe storm hitting the road to the Mercury Hotel and the late cancellation of one of the attendees. I'm waiting for new instructions.

Cheetah and Jane's computer, named Blacky have infraed their ID to the car's computer. A speech recognition device also confirmed their IDs. Now, Cheetah and Blacky are connected to the car's computer and have the privilege to use all available resources such as the speakers and all navigation services.

> **John**: Cheetah, re-schedule the rest of the meeting as early as possible. Show me the direction to my next appointment.

John has programmed a set of alternative policy rules for re-scheduling, such as delegating the responsibility to a remote agent when the bandwidth is low or disconnection rate is high or selecting the appropriate interface based on the result and the characteristics of the environment.

Cheetah launches a workflow that (1) calculates the time that it takes to go to John's meeting based on the weather report, distance, available fuel etc ... and (2) negotiates a new schedule with the remote scheduler agents of each meetings attendee via the available public wireless network.

Few seconds later a voice announces.

> **Cheetah**: Please listen to the new schedule I prepared for you. Monday 10.AM meeting with...
>
> A detailed schedule will be displayed on your rear view mirror once your car is stopped. Please confirm.
>
> **John**: Cheetah, confirmed.

During the the 2^{nd} movement of Mahler's symphony, Cheetah faintly displayed the new direction and the map to the next meeting on the front wind-screen as Cheetah detected that the rear mirror is not appropriate to display detailed maps. A voice interrupts the music again.

> **Cheetah**: John, I credited 30 dollars off your business credit card to pay the required road toll.

A voice interrupts the 3^{rd} movement of the symphony. It is Blacky.

> **Blacky**: Jane, Your son Tom is watching a movie called Terminator 12 on the home DVD. The movie is classified adults only.
>
> Tom had IDed the DVD to use it. The DVD automatically notify Jane each time Tom is watching a movie that is against the policy specified by Jane.

[1]The work reported in this paper has been funded in part by the Cooperative Research Centre Program through the Department of Industry, Science and Tourism of the Commonwealth Government of Australia.

Jane: Blacky, check if Tom has finished his home work. If not then stop the DVD and forbid Tom to use the DVD till further notice. Otherwise suspend the movie and send me 3 minutes play of the hottest sequences of the film .

Depending on how severely Jane's policies are crossed and the reachability of Jane, a home proxy can either take a local decision or ask Jane for instructions. In our scenario Jane was reachable.

Blacky checks the status of Tom's homework either by enquiring Tom's hand-held or by simply trusting him and displaying an interactive message such as "Tom, have you done your homework (YES/NO)" on a screen where Tom is looking.

Knowing that Tom was prompt to finish his homework the last two weeks, Blacky decided to send the interactive message on the screen and Tom answered YES

During the last movement of the symphony, Jane watches the hottest sequences on the front visor's screen. Then, she browses the web with a voice command interface to find different reviews of Terminator 12. Jane learns that the leading role in Terminator 12 is played by M. Lewinski.

Blacky: Jane, Tom has finished his homework.

Jane: Blacky, permission to watch Terminator 12 granted to Tom.

2 Introduction

The above scenario is original in a way that it contains complex multi-party interactions over a large scale mobile environment. The interactions are context-sensitive, exhibit Quality of Service specification and require advanced human-machine interfaces.

However the scenario is not as futuristic as we may think. The technology is already here to individually achieve each task mentioned such as the workflow engine, agent technology, automatic speech processing (speech recognition, speaker verification, language identification), event notification, localisation device (GPS Global Positioning System and active badge), e-commerce, mobile code, authentification services, mobile transactions, hand-held computers and wireless networks. Unfortunately they are proprietary or monolithic system unable to interact together and prevent the seamless integration of mobile devices into a truly open mobile distributed infrastructure.

Section 1 presented a realistic scenario. Section 3 outlines the trends of mobile computing. In particular, it identifies the parameters that drive mobile computing works, namely the market push and the international standard bodies and consortia efforts. Section 4 presents our vision of the future. It outlines problems and ideas that need to be addressed by the mobile computing research community. Section 5 gives an insight of how we can achieve the scenario presented in Section 1 with the current available technology. Section 6 concludes the paper.

3 Trends of mobile computing

The capacity of computing systems continues to increase at an ever quickening pace. This trend is evident in desktop and mobile devices where increased performance manifests itself as a proliferation in the number and types of services available. This section lists the international efforts and market influences on the integration of mobile computing.

3.1 Market push

The computing power of mobile devices and wireless networks will always be lower than the stationary and wired network counterpart due to the minitiarization requirements and power limitation of portable devices. We will always face the cliche mobile computing arguments such as: (i) wireless networks are slow, error prone, broadcast centric and expensive, (ii) mobile device are slow, have limited memory, are not ergonomic, have limited limited battery autonomy.

Despite the above limitations, analysts do expect the overall market for hand-held devices to become a true alternative to PC desktop and to grow in coming years, from 2.4 million devices shipped in 1997 to 8 million shipped in 2002 (Dataquest).

By the year 2002 Internet Commerce will reach more than 400 Billion US$(40 $\%$ growth) and the number of people accessing the World Wide Web will hit almost 320 million. On the other hand there are 32 million mobile phone users worldwide today, a third of the total work force (Oracle Corp). The two quotes suggests that the convergence between telecommunication manufactures mobile phone protocols and IP is irremediable as mobile users would like to access Internet services from their mobile phone.

3.2 Standardization efforts

In order to achieve interoperability, international consortia and standardization bodies such as the ISO (International Standard Organization), OMG (Object Management Group), W3C (WWW Consortium), IETF (Internet Engineering Task Force), SS7 (Signaling System) and TINA (Telecommunications Information Networking Architecture Consortium) have released standards specification for open distributed system. These bodies shape the IT landscape and increasingly release mobile computing related specifications.

Interoperability efforts are situated at three complementary levels. (i) At the architecture level defining the notion of distributed objects and concepts to access and bind them. This also addresses scalability issues. (ii)At the application level where a set of standard APIs to access and provide services are defined. (iii) At the protocol or network level. This allows independent wireless networks and physical mobile devices to communicate with each other. It also addresses the characteristic specifications of hardware.

3.2.1 Architecture layer

The ISO RM-ODP (Reference Model for Open Distributed Processing) and OMG are the two major international standard bodies that have defined useful concepts for the use of mobile computers at the Architecture layer.

RM-ODP [6] is a framework for the standardization of Open Distributed Processing. It creates an architecture within which support for distribution, inter-working and portability can be integrated. It is positioned as a generic platform for future telecommunication services.

OMG [7]: The Object Management Group has released the CORBA services needed to build Mobile infrastructures. These include: A messaging Service defining AMI (Asynchronous Method Invocation), MASIF (Mobile Agent System Interoperebality Facilities), Lifecycle service and Component service.

3.2.2 Application layer

The current approach in distributed computing is to make the underlying network and the physical distribution transparent to upper layers such as the application. These are not suitable for mobile computing because constraints brought by mobile devices are physical and can hardly be hidden from the upper layer. The following list outlines the major efforts for interoperability at the application layer.

- **Jini** [5] Jini enables spontaneous networking of a wide variety of hardware and software - anything that can be connected. It basically simplifies interaction with networks.
- **W3C** [10]: The WWW Consortium is working towards making information on the World Wide Web accessible to mobile devices . W3C's Mobile Access Activity is ensuring that the protocols and data formats of the Web provide an effective fit for mobile devices by defining a compact HTML.
- **General Magic**[4]: Portico integrates, many types of communication such as, voice mail, outgoing fax, email, and more, into a conveniently single friendly service accessed by a voice interface.

3.2.3 Protocol layer

The main catalyst of the integration of mobile device into the fixed, wired stationary network is the cellular mobile phone. However the compatibility between wireless networks is absent and drastically limits its use.

- **Bluetooth**[1] is a technology specification for small form factor, low-cost, short range radio links between mobile PCs, mobile phones and other portable devices. Bluetooth envisions access to the Internet either via a wireless connection routed through a mobile phone, through a wired connection such as the public switched telephone network, through a high-speed ISDN line, or through local area data networking equipment.
- **WAP** (Wireless Application Protocol) [9] defines a global wireless protocol specification to work across heterogeneous wireless network technologies. A joint work with the W3C produced WML: Wireless Markup Language. which is a lightweight procedural scripting Language. **SWAP** is a specification that combines DECT(Digital Enhanced Cordless Telecommunication.) and Physical layer IEEE 802.11. This makes it compatible with TCP/IP and the DECT/GAP protocol for voice transfer.[8]
- **Mobile IP and IPv6** [2, 3] is an IETF (The Internet Engineering Task Force) standard. Mobile IP develops architectures and protocols to support mobility within the Internet. It address support for transparent host "roaming" among different subnetworks and different media (e.g., LANs, dial-up links, and wireless communication channels). IPv6 is the next generation of IP protocol.

4 Future: connecting offices, homes, cars and hand-helds

An open infrastructure that allows access, reconfiguration, deployment and movement of components from anywhere at anytime is the aim for the years to come. The next great market will belong to the software and hardware that enables the above vision.

The infrastructure will integrate mobile technologies that have higher speeds, higher battery autonomy, low cost, consistent quality of service and coverage of real-time multimedia information. This will allow video-conferencing, satellite, radio, infra-red and Internet connection from mobile and stationary networks. We believe that the current available technologies have such properties but again, they are not interoperable. Therefore, integration of mobile technology has to follow a clear and sound software engineering methodology that tackles the Architecture, Application and Protocol levels.

4.1 Protocol layer

This section shows our vision of the future of hand held computers and mobile networks.

4.1.1 Mobile devices

As suggested in section 1, we foresee palm size computer that interoperates with different wireless networks, mobile phone networks (Universal Traffic Management System-UTMS and Iridium) and even TV networks. A hand held machine should have advanceed ergonomical human-machine interface. It should have location aware devices such as GPS. Its size should be as thick as a credit card with a foldable A4 screen display to allow decent web browsing or TV watching. Such a device will play the role of an assistant and could replace Id, passport, driver license and credit cards.

4.1.2 Network layer

Delivering Internet Protocol-based services over Telco wireless broadband networks such as UTMS and other mobile phone protocols is a pre-requisite for achieving a successful integration of mobile computing into a multimedia distributed system.

Researchers are working on the interoperability between Wireless Protocol (UTMS-Iridium ...), IPv6, mobile IP and Wireless ATM (Asynchronous Transfer Mode). The most promising long-term solution to support the integration of multimedia services similar to B-ISDN with wireless network is Wireless-ATM. Security protocols are now designed at the network protocols level (e.g Embedding encryption at 802.11). Work has to be done about changing dynamically the security policies according to the environment. The compatibility between different authentification protocols also has to be investigated.

4.2 Application layer

As components will be able to move everywhere and wake up in a completely unknown and untrusted environment, there is a need to define APIs that allow:

- change of behaviour and the QoS specification of a component according to the environment (mobile or stationary) where it runs. (e.g in section 1 the hand-held computer Cheetah dynamically changes its behaviour by deciding to project the map at the wind-screen because the rear mirror is not suitable for map display)
- identification and measurement of the environment's characteristics in order to determine if a component can perform its task or if it has to trigger other tasks.
- a generic way to lookup location dependent services (e.g find the speakers of the car in section 1. The discovery of a mobile service has not been clearly addressed by current technology such as Trader or naming services.

Many laboratories are now working on human-machine interfaces that aim to improve human-computer interactions. Cognitive psychology and ergonomics make it possible to better adapt computer systems to the needs of their users depending on the context of the user. For example while a user is driving it is nonsense to send him any text to be read.

4.3 Architecture layer

Agent technology is receiving increasing visibility as a way of making information more available and usable. Agents perform on behalf of an application or another agent and have the ability to move and make local decisions.

Agents perform actions following policy rules. Policy rules can be very simple statements similar to Event-Condition-Action or can be high level enterprise statements featuring notions such as permissions, prohibitions, obligations, ownership, right objective, authority, delegation or trust.

The specification as well as the monitoring and the enforcement of such policies haven't been clearly solved yet. We believe that the type of environment where users or components evolve (wired or wireless) will impact on the specification and the enforcement of such policy. For example, the low security and the disconnection properties of a mobile environment might effect the notion of trust between interacting components. Therefore there is a need to find policy modeling concepts that take into account mobile users requirements. The RM-ODP enterprise modeling [6] is working in this area.

5 How to achieve our scenario

In terms of networkng, the wireless communication protocol specification between hand-held, car and home will be achievable with the implementation of the recently released WAP and Bluetooth [1, 9] specifications.

The schedule of John is maintained by agents. Agent architecture can be built on top of the above communication infrastructure. The multi-party coordination model of agents allow to gather information from different agents (attendees, weather report, car) [6]. The infrastructure must also have built-in dynamic (real-time) QoS management and specification [7].

Jane watches the *hotest* sequence of Terminator 12 on the front visor's screen. Pictures are sent from home.

The quality of the pictures depends on the available bandwidth, the size of the screen, the meaning of *hot* and the duration of the display. Each of these characteristics fluctuates significantly. For example, the duration of the display can be shorten if the agent knows that the car will reach the destination soon. Therefore the adaptation mechanism requires feed back from the application. Many research laboratories are working toward the specification of application-aware adaptation infrastructures.

John issued transaction from his car to pay the road toll. Electronic banking from a mobile environment is yet to be improved for security and scalability reasons. Jane also issued a transaction to read reviews about Terminator 12. Unfortunately the result is not accurate. This might due to a QoS specification that requires a rapid response at the expense of accuracy of the result. Accordingly, the infrastructure has to have a transaction monitor that provides "less than" ACID properties. The trade between performance and consistency is crucial in a mobile environment. For example, a degraded service might be acceptable if a bandwidth is low. This poses the question of how the users will be invoiced when the quality of the received service fluctuates.

The specification and enforcement of different policies that John and Jane apply to their son Tom are complicated and require policy manager. Such adaptable policy can be inhibited/activated depending on the QoS provided by the environment [6].

Blacky displays a message on a screen where Tom is looking. Interfaces which are aware of human senses such as voice recognition, position of eyes... are already flourishing in the market despite their price and their monolithic status that prevent them from being integrated in an open infrastructure.

6 Conclusion

Due to space limitation, we haven't outined on-going research works. This paper offers a realistic scenario, a survey of market influences and standard efforts related to mobile computing. The technology identifiable today must be tightly integrated into a coherent infrastructure that will allow us to have a global roaming services.

Nowadays, our cars feature more electronics than the spaceship of Neil Armstrong in 1969. Nobody expected that 30 years ago. That is to say that the future is difficult to predict. However the future doesn't belong to intrusive "intelligent" robots or wearable devices which reminds us of Star-Trek. New mobile technology will be rather non-intrusive, ubiquitous, invisible, useful, calm and peaceful.

By the beginning of the next century, computers, TVs, telephones, and more will be connected with radio waves or other wireless technology, freeing consumers from the spaghetti of wires that connect their electronics. Therefore we have to build a clear open mobile infrastructure that integrates, legacy systems, adaptable and scalable enough to follow the rapid change of technology. An infrastructure that is easy to use via new context-sensitive ergonomic concepts.

By providing new, easy to use, cheap and exciting technology, new patterns of behaviour, new market, new type of interactions, new types of collective work and not to forget new crimes will appear. With the stationary distributed system technology, the world came to our desktop, now with the new wave of mobile technology, not only the world will become reachable from anywhere at anytime but the desktop has expanded to feature day-life activities. Therefore we must give a serious thoughts about the social impacts of the coming technology.

References

[1] "Bluetooth" `http://www.bluetooth.com`

[2] RFC 1883 *Internet Protocol, Version 6 (IPv6) Specification*

[3] RFC 2002 *Internet Protocol Mobility Support*

[4] "General Magic" `http://www.genmagic.com/`

[5] "The Jini System Software Development" `http://www.javasoft.com/products/jini/index.html`

[6] ISO/IEC 10746-1 10746-2 10746-3. " Basic Reference for Open Distributed Processing." `http://www.iso.ch:8000/RM-ODP`

[7] OMG: The Object Management Group. Technology Adoptions `http://www.omg.org/techprocess/meetings/schedule/Technology_Adoptions.html`

[8] SWAP - Shared Wireless Access Protocol - Voice and Data communication `http://www.homerf.org/press/`

[9] WAP - Wireless Application protocol Specification v1.0 `http://www.wapforum.org/`

[10] World Wide Web Consortium - Mobile Access Activity Statement `http://www.w3.org/Mobile/Activity`