Building a Virtual Device on Personal Area Network

Tore E. Jønvik
Unik – University of Oslo
Snaroyveien 30 –1331 Fornebu, Norway
tlf: +47 90199176
tore-erling.jonvik@telenor.com

Paal Engelstad
Telenor R&D
Snaroyveien 30 – 1331 Fornebu, Norway
tlf: +47 416 33 776
paal.engelstad@telenor.com

Do van Thanh
Telenor R&D
Snaroyveien 30 – 1331 Fornebu, Norway
tlf: +47 909 77 10 2
thanh-van.do@telenor.com

Abstract: **In this paper we introduce a novel concept, which proposes to consider all the independent devices on the user 's Personal Area Network as one big "Virtual Device" having multiple input and output units and providing a coherent and surround interface to the user. Such a concept is quite valuable to the user since it allows him to manage all his devices as one. The paper also proposes and describes a PAN middleware that enables the formation of a Virtual Device on the PAN and that is capable of handling the dynamical presence of devices and the diversity of device types. In order to identify the necessary capabilities and functions of such middleware, four PAN configurations, namely Isolated PAN with unique Open device, Isolated PAN with multiple Open devices, Networked PAN without Open device, Networked PAN with Open device are considered thoroughly.**

1. INTRODUCTION

Although mobile and portable devices are getting more and more advanced and incorporating more functions, it is foreseen that in the future a user will make use of more and more devices such as mobile phone, PDA (Personal Digital Assistant), headset, microphone, digital camera, digital camcorder, etc. The user will have to manage all of them and it is not always an easy task even for technicians. It would be nice if the user can consider all the independent devices as one big "Virtual Device" having multiple input and output units and providing a coherent and surround interface to the user [1], [2].

Other advantages of the Virtual Device concept are the cost reduction and the increase of convenience. Devices can share resources like processing power, battery power, memory, data, applications, network access points and user-interfaces. The user does not have to purchase the same resource twice and can hence save money. It is also more convenient for him to carry as less equipment as possible when moving. It is also highly desirable seen from the user's point of view to have a unique user profile to deal with. Nowadays with several devices the user has to set up and define his profile for each of them. When he wants to modify something he has to do it on all of them. Another inconvenience is that when replacing older devices with newer ones, the user must also move his profile to the new ones or redefine his profile.

With the emergence of local short-range communication

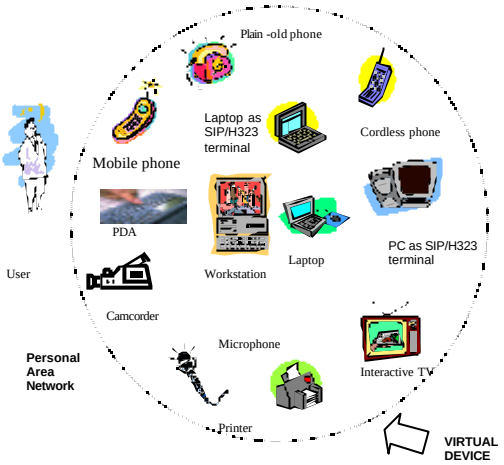

Figure 1 The Virtual Device on PAN

technologies such as Bluetooth [3], WLAN [4], HiperLAN, etc. local connectivity between devices is enabled. The devices belonging to a person will form a private Personal Area Network (PAN) where devices appear and disappear dynamically. However, most importantly, connectivity does not necessarily mean communication and many challenging issues must be resolved before devices can collaborate and together form a Virtual Device. This paper proposes and describes a PAN middleware that enables the formation of a Virtual Device on the PAN and that is capable of handling the dynamical presence of devices and the diversity of device types.

2. PAN OVERALL ARCHITECTURE

In order to realise the Virtual Device, the PAN and his devices must be hidden to the user and his applications and this is done by introducing a PAN middleware.

As shown in Figure 2 the PAN middleware must be capable of handling not only the Personal Area Network but also the heterogeneity and the dynamic of devices. There are precisely these two characteristics that make the PAN middleware

different from the traditional Distributed Computing Middleware where the computing nodes are supposed to be stable and equal or at least having the minimum of capabilities e.g. processing, storage, communication, etc.

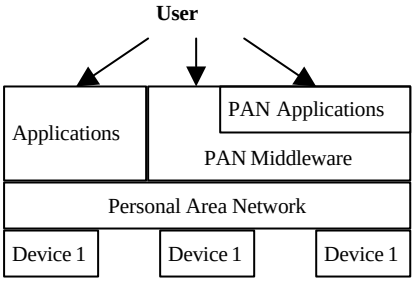

Figure 2 PAN overall architecture

Indeed, on the PAN there are a variety of devices such as:

- Communications devices (fixed, mobile &IP phones)
- Computing devices (Computer, PC, laptop, PDA, etc.)
- Peripheral devices (Printer, scanner, digital camera, camcorder, etc.)
- Electronic devices (TV, stereo equipment, loudspeakers, etc.)
- Electronic appliances (fridge, expresso machine, washing machine, etc.)
- On-body or Off Body
- Mobile or stationary
- With or without Network connections
- With or without local wireless connections

It will be necessary with a careful and unambiguous definition of device types but for the time being it is sufficient to consider the device types at a coarse level as follows:

- **Primitive device:** Simple devices that cannot operate alone but are slave to other devices, e.g. earphone, microphone, display, etc.
- **Open device:** Devices allowing the installation and execution of PAN Middleware and other applications, e.g. PDA, laptop, workstation, etc.
- **Closed device:** Devices that can operate stand-alone but are like a black box i.e. its internal structure and functions are totally hidden and communicate with the environment though only well defined interfaces. For instance, a digital camera is advanced device having processor, memory, input and output units but does not allow the installation and execution of foreign applications. It communicates with the rest of the word via interfaces like serial, parallel, USB, etc.

In order to identify and define the capabilities and functions in the PAN Middleware (PANM) let us consider successively four PAN configurations as follows:

- Isolated PAN with unique Open device
- Isolated PAN with multiple Open devices
- Networked PAN without Open device
- Networked PAN with Open device

3. ISOLATED PAN WITH UNIQUE OPEN DEVICE

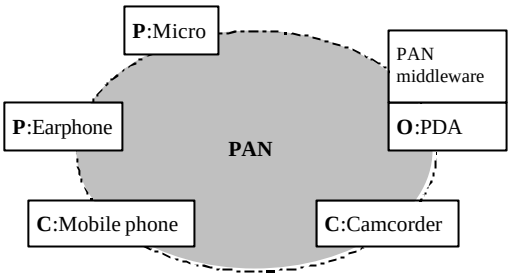

Figure 3 A PAN with unique Open device

In this PAN configuration, there is no device having connection with any wired or wireless network. There is only one Open device while the rest is either Primitive or Closed. Figure 3 shows a PAN with two primitive devices: microphone and earphone, two closed devices: Mobile phone and Camcorder, and one Open device: PDA. In such a PAN it is desirable to achieve the following:

- All the Open and Closed devices should have the ability to use the Primitive ones i.e. the mobile phone, the camcorder and the PDA should be able to share the microphone and the earphone. It is worth noting that today, such a device sharing is not supported with Bluetooth.
- The Open devices should have the ability to use Closed devices. This is possible although very dependent on the interfaces offered by the Closed device. For example, the PDA can only communicate with the mobile phone using the AT command [5] to make e.g. a call request.
- The Closed devices can only user other Open or Closed devices if they are programmed for that.

A PAN middleware is necessary to achieve the resource sharing as above. In this case only the PDA can accommodate the PAN Middleware (PANM). Let us now identify the necessary capabilities and functions for this configuration.

3.1 Device Profile

The PANM should be able to detect and to recognise what are the devices present in the PAN, what type they are and what capabilities they have or what service they are offering, e.g. printing, sound input, text displaying, etc. The definition of device types must be logical and unambiguous definition of device types. It must be logical to address both composite devices and inherited devices. It must be unambiguous to guarantee the identification of a device type. Ideally, the definition of device types should be standardised.

3.2 Device Discovery and Updating

To support the PAN's dynamic where devices appear and disappear, the PANM should be equipped mechanisms for

Device Discovery and Updating. One alternative is to carry out polling periodically. Since Primitive devices may be tied to their master and not visible to other, the PANM should also ask also Open and Closed devices for Primitive devices connected to the device. In a second alternative, the PANM only run the device discovery once and relies on triggering from the network layer to update its device set. In a third alternative, the changes are only updated when an attempt to reach a device upon request from an application fails.
The PANM should also store the present devices. It is hence necessary to have a naming convention, e.g. PDA 1, Mobile 2, etc. The network addresses (IP, Blutetooth, etc.) and protocols for each device must also be saved.

3.3. Device Input and Output redirection

The PANM should be able to redirect an output stream from one device to the input stream of another one. For example the sound output stream from the PDA can be redirected to the earphone and the sound input redirected to the microphone. It must intercept the output stream addressed to a device at an output port, perform the necessary transformation and send it to another device on the PAN. An API (Application Programming Interface) should be defined

3.4. Application/Service Input and output redirection

The input and output redirection should also be done at the application/service level, i.e. one application can be redirected to one device while a second one to another device. However, this capability is more difficult since it depends on the feature of the operating system and may also require a new application structure as shown in Figure . An application consists of three components: *Core, Input and Output*. The *Core* component contains the main logic of the application and should remain invariant. The Input and Output Components should be specified according to the services supported such as sound input, text input, graphic display, colour printing, etc. If a device offers a service matching the one required then it can be used for the application.

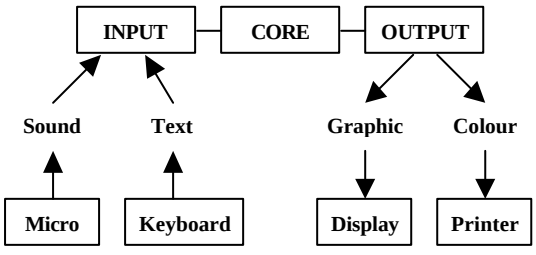

Figure 4 PAN application structure

3.5 User Profile

The user and owner of the PAN should be reserved the right to define the following:

- What devices are allowed to participate to his PAN when present within the PAN's coverage.
- How the devices should be used at a particular location or at a particular time or according to a certain timetable. How should the redirection between devices be
- Which device should be internal and which one should be global and visible to the outside world.
- Which applications and their settings
- How should the applications should be distributed among the devices, i.e. how the three components should distributed among devices according to criteria as quality, price, battery level, etc.

In addition, the user must have the ability to alter, remove, and add device and applications at any time and anywhere. These hard requirements put quite a lot of challenge on the design of the User Profile structure and the architecture of the system around it.

3.6 Interface to the user

Since the user, as owner of the PAN, should be the one having the right to decide everything, there is a need for an application called *PAN Control* that offers interfaces allowing him/her to communicate and control the PAN Middleware. As other applications, the *PAN Control* should be also structured as Core, Input and Output and should support a variety of input and output services.

3.7 Interface to applications and services

With the apparition of the PAN, a brand new type of applications called *PAN-based applications* is born. This new type of applications will actively take advantage of the unique properties of the PAN: device dynamic and resource sharing. A typical example of PAN-based applications is an application, which focuses on the control of existing applications, their parallel execution, their flexible and dynamic composition, the distribution of their input and output. The PANM should provide an Application Programming Interface (API) allowing the application access to the PAN capabilities and functions. It is also necessary with careful study to decide which technology, e.g. Java, CORBA, XML Web service, etc. should be used to implement such an API:

3.8. Summary

As shown in Figure 5 the necessary capabilities and functions in the PAN Middleware (PANM) in the case of an isolated PAN with unique Open Device are:

- Device Profile
- Device Discovery
- Device Redirection
- Application Redirection
- User Profile
- PAN Control

- PAN API

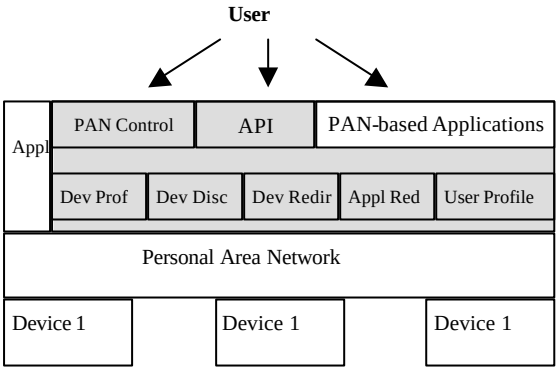

Figure 5 The PANM for PAN with unique Open Device

·This PAN configuration depends totally on the central device, the open device and will collapse when the open device disappears, is switched off or runs out of battery. Another disadvantage is the limitation of the resource sharing since most of devices are Closed and Primitive and hence impenetrable.

4. ISOLATED PAN WITH MULTIPLE OPEN DEVICES

In this PAN configuration, there are now multiple Open devices, multiple Closed devices and multiple Primitive devices. Figure 6 shows a PAN with two Primitive devices: microphone and earphone, two Closed devices: Mobile phone and Camcorder, and three Open device: PDA, Laptop and PC. In such a PAN, in addition to the features identified for the previous case it is desirable to achieve better collaboration and more optimal resource sharing between the Open devices. We present now successively all the possible alternatives to achieve improved Resource Sharing.

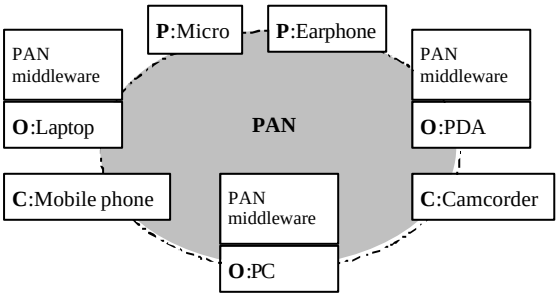

Figure 6 A PAN with multiple Open Devices

4.1 Distributed Operating System

In this alternative, the PAN Middleware is a Distributed Operating System deployed on all the Open devices and coupling them tightly as one. Such an alternative demands the implementation of the Distributed OS on all the Open device types and with the rapid growth in type of mobile devices this could be difficult. Another disadvantage is that the device dynamic can create serious problem for the Distributed OS that requires much stability.

4.2 Distributed Computing

In this alternative, the PAN Middleware is a Distributed Computing Middleware, which hides the distribution and communications from the applications and application developers. In order to be able to support PAN, the traditional Distributed Computing Middleware must be extended with functionality to cope with the dynamic of devices. This alternative has an advantage compared to the previous in the sense that there are fewer operating systems and the number of Middleware implementations is lower. On the other, it is important to quantify the overhead introduced and to investigate whether it is acceptable for mobile devices with limited processing and storage capabilities and battery life.

4.3 XML Web Services

In this alternative, the PAN Middleware consists of the logic necessary to expose the capabilities and functions of each Open device as an XML (eXtensible Markup Language) Web services [6]. The other Open devices can hence invoke these Web services by using SOAP (Simple Object Access Protocol) [7]. With the Web service concept unlike the Distributed Computing the distribution is not hidden. Entities know that communicate with remote entities but communication is made simpler by the automatic generation of SOAP message. This alternative requires that a Web service platform is installed on each Open device offering Web service and this could create an overhead to the PAN. However, the devices are more loosely coupled in this alternative and it can cope better with device dynamic.

4.4 Application distribution, coordination and control

In this alternative the PAN Middleware performs the distribution, coordination and control of applications based on the application structure: Core, Input and Output. The distribution of the input and output components is already taken care by the Application Redirection Function mentioned earlier. Concerning the Core, it could only be moved and resumed on compatible Open device, i.e. devices capable of supporting it. For example, an application Core written in Java can only be moved to a device having a Java Virtual Machine and not to a MS Windows device. To achieve the application migration, the mobile agent concept can be appropriate since an agent can stop the execution of an application, serialize it, transport it to another device, de-serialize and resume the execution.

4.5 Summary

To achieve optimal resource usage a Resource Sharing function is required in the PANM as shown in Figure 7. There are four approaches that need to be investigated further.

However, we believe in the coexistence and the combination of several of these approaches.

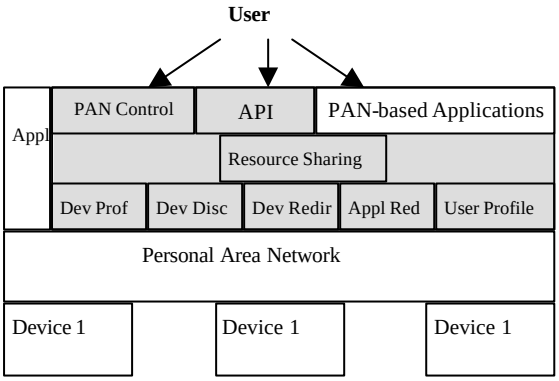

Figure 7 The PANM for PAN with multiple Open Devices

5. NETWORKED PAN WITHOUT OPEN DEVICE

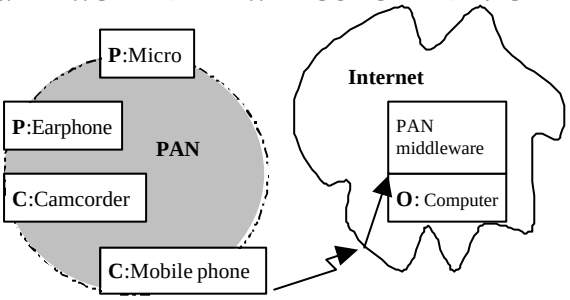

Figure 8 A Networked PAN without Open device

In this configuration the PAN does not have any Open device but only either Primitive or Closed device. Usually as mentioned in section II, without an Open device, the PAN will collapse but fortunately there is a way to remedy the situation if there is one device with network connection. As shown in Figure 8, the mobile phone allows communication with a Computer running PAN Middleware. In this case the PAN can function very well because it is logically equivalent to the configuration Isolated PAN with unique Open device if the Computer on the network is considered as a PAN device. This configuration is, however, very interesting since it opens for several relevant usage. Indeed, the network computer can be Home PC or the office workstation that the user always leave behind when traveling but it can still participate and give support to his PAN. This network computer can also be provisioned and managed by a Service Provider that offers PAN service to the users.

6. NETWORKED PAN WITH OPEN DEVICE

In this configuration, the PAN has all the device types: Open, Closed and Primitive but also those having network connection. This configuration is logically equivalent with the Isolated PAN with multiple Open devices. However, as shown in Figure 9 in order to reduce the usage of the network connection, it is perhaps desirable not to have tight coupling between the PDA on the PAN and the network computer. Only initiation and synchronisation should be allowed.

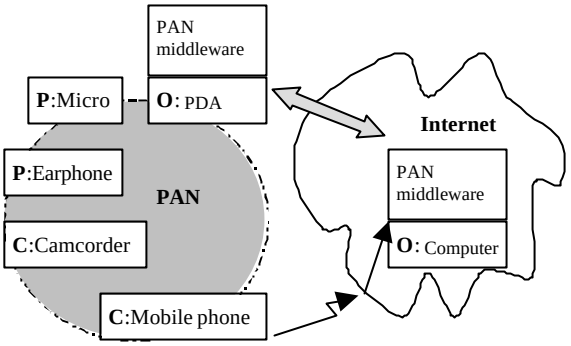

Figure 9 A Networked PAN with Open Device

7. CONCLUSION

In this paper we introduce a novel concept, which proposes to realise a Virtual Device based on independent devices on the Personal Area Network. We also propose a PAN middleware necessary for the realisation of the Virtual Device. The capabilities and functions of the proposed PAN Middleware are identified and explained. However, we are still in the analysis phase. In order to obtain a running PAN Middleware, the design, implementation and testing should be carried out and many challenging issues such as the device discovery, the design of the user profile, the choice of appropriate approach for resource sharing, etc. must be treated. Last but least, the PAN will only take off with the wide availability of short-range wireless technologies that consume less energy.

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