WIRELESS WORLD
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An IEEE 802.21-based Universal Information Service

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***Abstract* — Increased mobility and a heterogeneous network environment result in mobile devices frequently connecting to new access networks about which they lack information. Providing information about those access networks, supported local services, and information about the current usage context could enable mobile devices to automatically adapt to their environment. Such self-adaptation significantly reduces the need for human intervention and improves the mobile computing experience. To provide mobile devices with this information, we propose an architecture for a *Universal Information Service*, especially taking into consideration local access networks. This architecture is based on, reuses, and extends the infrastructure components of the emerging IEEE 802.21 standard, hence reducing deployment obstacles.**

***Index Terms* — Automatic service configuration, context-aware services, handover, IEEE 802.21, self-configuration, service discovery**

1. Introduction

During the last several years the usage of mobile devices (e.g. PDA, laptop) and small mobile networks (e.g. Personal Area Networks) has significantly increased. At the same time, evolving technologies like UMTS, WLAN, and WiMAX have not resulted in one single global access network but have further increased the heterogeneity of access technologies. The existence of each access technology is justified by their different characteristics; heterogeneity will remain for the foreseeable future. Therefore, for the mobile entity (i.e. device or network) increased mobility results in frequently changing between (heterogeneous) access networks. These conditions have to be dealt with. Systems have to be able to adapt to changing access networks and changing environments automatically without bothering humans to intervene in order to make mobile computing feasible, e.g. the user does not want to install and configure a new printer driver when temporarily connecting to a new network.

To adapt to such changes, the entities need information about the environment, including various information about the access network itself (e.g. a cellular provider's UMTS network or a private WLAN), information about services supported by this access network, as well as more general information about the current context in which the mobile entity resides. To consistently provide such information, we propose a *Universal Information Service*.

To achieve these goals, some kind of infrastructure is needed. But integrating new infrastructure elements for new services into global networks is very problematic. Hence, reusing existing infrastructure elements from other standards is advisable. The evolving IEEE 802.21 standard [1] defines an infrastructure intended to improve mobile devices' handover decisions based on mainly lower-layer information from both mobile devices and the access network. The infrastructure is used for the special case of handover optimization, particularly between heterogeneous networks. We argue that the basic IEEE 802.21 infrastructure components can be used in a much more general way. Therefore, we use those components to build the Universal Information Service, avoiding the need for additional new infrastructure elements.

In the present paper, we will specifically highlight two aspects of the Universal Information Service. First, we discuss discovery and configuration of services (Section 0). Unlike Service Oriented Architectures (SOA) [2] that focus on higher-layer (web) services in flat networks with an underlying homogeneous infrastructure (TCP/IP), we specifically incorporate local services that are bound to the access network. Furthermore, our architecture explicitly takes into account lower network layers so that information from heterogeneous access networks can be used. Services that could be supported include both higher-level services like printing or video services that take into account the link quality, as well as lower-level services like location services or services of connected wireless sensor networks.

Service discovery is a key aspect to automatically adapt to changing environments. Several different service discovery mechanisms have been proposed so far, some relying on a central repository like Java-based Jini [3], several other ones – like UPnP [4], Bluetooth [5], or DEAPSpace [6] – support a distributed architecture or can support both communication schemas like SDP [7], SLP [8], DAEDALUS [9], or Zeroconf [10]. By using and extending the IEEE 802.21 infrastructure components, we avoid the need for extra infrastructure elements that are required by centralized approaches. At the same time, by reusing the IEEE 802.21 infrastructure, we are able to discover services *before connecting* to a new access network.

In the second part of this paper we discuss how the Universal Information Service can provide further information about the environment to support context-awareness of services (Section 2.3). Current research in the field of context-awareness focuses on several different areas, including context modeling [11], models for programming context-aware applications and architectures for context-aware services [12], [13], [14]. We argue that a mainly device-based architecture for context-aware services is not sufficient as mobile devices are limited in the amount of “sensor” information they can deliver due to limits of cost, space, and availability of information (i.e. some kind of information is just available from the network). Therefore, we improve upon existing context-aware architectures by introducing a new framework for context-aware services that explicitly incorporates the discovery and access of sensors within the network, while benefiting from the reuse of the IEEE 802.21 infrastructure. Thereby, services can rely on “sensor” information from both the access network and from mobile entities (and possibly even more data sources). By supporting mobile devices as well as mobile networks, we incorporate the increasingly important aspect of inter-network communication, also explored by projects like Ambient Networks [15].

We will address architectural considerations and discuss required extensions to the basic IEEE 802.21 components. This paper describes work in progress.

2. Universal Information Service

The Universal Information Service requires three basic infrastructure components: First, to provide the mobile entity with information, an *information service* is needed to store and deliver data. Second, a trigger or *event service* is needed to inform the mobile entity about changes in its environment. Third, there is a need for a *command service* to react and adapt to changes and interact with the environment. This command service can be used to trigger actions (e.g. initiate a handover) and manipulate sensors/actuators inside mobile devices as well as the access network.

The evolving IEEE 802.21 standard defines those three components, yet only for the special case of handover optimization. Fig. 1 shows the basic IEEE 802.21 architecture. Reusing and extending the IEEE 802.21 infrastructure components brings about several advantages besides avoiding the need for extra infrastructure. First, the Universal Information Service will be widely available as the IEEE 802.21 standard is designed to support a wide variety of different access technologies. Second, the handover background imposes certain demands concerning latency that our system can directly benefit from, facilitating the support for time-critical services.

In the following sections, we will introduce a typical usage scenario and describe how the basic IEEE 802.21 components can be used to support general service discovery and configuration as well as an infrastructure for context-aware services.

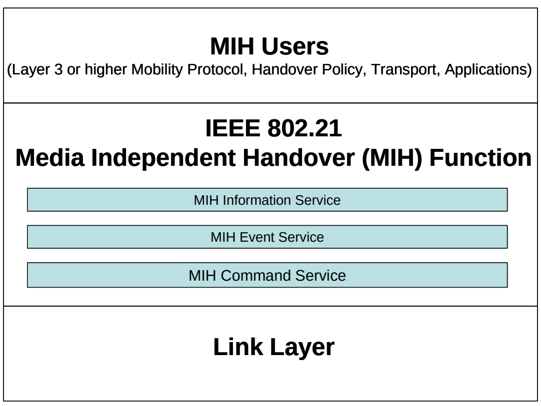

Fig. 1: Basic IEEE 802.21 architecture

2.1. Usage scenario

Consider the following scenario: you are on your way to visit a friend. You surf the web via UMTS with your PDA while sitting in the bus. When entering your friend's home, your PDA automatically detects his private WLAN. The IEEE 802.21 standard will facilitate the automatic handover to your friend's WLAN, giving you better data rates and free access.

You want to show your friend some snapshots stored on your PDA. After connecting to your friend's network, the Universal Information Service has automatically informed your PDA about an available networked TV and now supports your PDA to connect and use this TV automatically to display your pictures after verifying your identity. Section 0 will describe the service discovery and configuration in more detail.

You set a reminder on your PDA to give a friend a call when you enter the context "At home" after 9pm (he will not be reachable before 9pm). Instead of going off at 9pm (you are still at the gym), the Universal Information Service informs your PDA when you enter the context "At home", making the reminder go off when you arrive back home at 9:30pm; ordinary reminders often go off in inappropriate situations. Section 2.3 will describe an IEEE 802.21 based infrastructure to enable such context-aware services.

2.2. Service discovery and service configuration

The IEEE 802.21 standard contains a basic information service that provides information to enable better handover decisions. The provided information includes mainly static information about lower layers such as neighboring access networks and other link layer information as well as information about a limited set of available higher-layer services like QoS and internet connectivity that could influence the handover decision.

We leverage this structure in several ways. We extend the IEEE 802.21 infrastructure to support a much wider variety of services. IEEE 802.21 uses a schema to define the structure of information elements and their relationship (e.g. using the Resource Description Framework (RDF) [16] and the OWL Web Ontology Language [17]), making it easy to extend the set of supported services. As described earlier, we specifically support services that are bound to the local access network. Those services in turn can access other services (like authentication) on the Internet.

IEEE 802.21 connects to its information service especially *in advance of a handover* via the current access network (e.g. UMTS) to request information about supported services of a candidate access network (e.g. WLAN). We leverage this ability for our extended set of supported services, thereby enabling the discovery of available services before connecting to a new network. Furthermore, we use our Universal Information Service to deliver information on how to configure the supported services *after a handover*. This can include information on how to use a service, how to configure it, as well as how to control access to services.

Our Universal Information Service thereby enables mobile entities to automatically discover and configure available services when connecting to a new access network, using the same infrastructure that is used to support the handover decision.

One way to reuse and extend the use of the individual IEEE 802.21 infrastructure components is demonstrated in the following example, based on the usage scenario from Section 2.1. When connecting to your friend's WLAN, the event service is used to automatically inform your PDA of newly available service of this access network, including the printing service. Before printing, the command service can be used to request additional information on how to configure the printer from the information service, which hosts all necessary information about available services.

Our supported set of services as well as the services themselves can be dynamic. As the IEEE 802.21 information service is primarily concentrating on static information, we have to extend the information service to support a flexible service registration mechanism.

2.3. Context-aware services

The basic concept of our context-aware services framework is to use the main IEEE 802.21 components to support a three-tier architecture consisting of a sensor, a convergence, and a service tier (see Fig. 2).

The sensor tier encapsulates "sensors" (in a generalized sense) that deliver information about

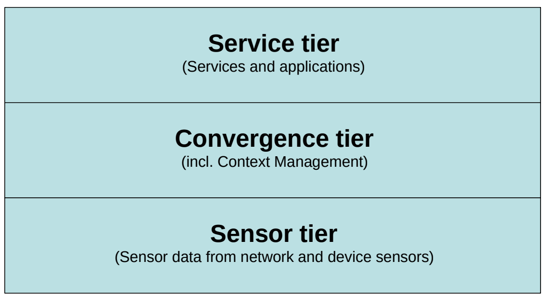

Fig. 2: Three tier architecture for context-aware services

the environment and can reside within mobile devices (e.g. GPS, network interface data) as well as within the access network (e.g. position, temperature). The position information needed to verify the context "At home" in Section 2.1 could either be obtained from a GPS sensor inside the PDA as well as from network-based triangulation data.

The second tier will collect sensor data and will construct *contexts* from that data. A context is a logical combination of (sensor) data, representing a specific situation. Contexts can additionally take into account data feeds delivering supplementary information, e.g. the cinema program or a conference schedule. An example of a context for a researcher would be "Giving a talk". This context could be based on position data and data from his schedule. When both components match, one enters the context "Giving a talk".

The third tier represents services and applications that use the underlying information to offer context-aware services. The architecture describes how context-aware services can access context-information from both inside the mobile entity and from inside the network.

The advantage of this three-tier approach is that each tier can be advanced and extended separately. New services and applications can be developed on the third tier independently from the other tiers. Better algorithms can be implemented on the second tier to improve the contexts that services and applications registered to, improving the accuracy of the context calculation. In the first tier, new sensors could be added to provide new or more accurate data for the second layer.

Now the question is: how do we match this three-tier architecture with the existing IEEE 802.21 infrastructure? Fig. 3 gives an overview of the combined architecture. First, the communication between the three tiers relies primarily on the event service. Contexts on the second tier can register for data from specific sensors. We generalize the IEEE 802.21 *Link Event Registration* to be applicable between tier one and two. The IEEE 802.21 event transportation mechanism can be used to deliver events from the sensors (which can reside within the network as well as within mobile devices) to the registered contexts. Besides using events, the command service can be used to access sensor data explicitly as well as to manipulate sensors.

Correspondingly, tier three services register for tier two context events using a generalized form of the IEEE 802.21 *MIH Event Registration*. Services can register for different kinds of context events, e.g. entering or exiting a specific context. When entering the context "Giving a lecture", your mobile device could switch to "mute" automatically and could switch back to "normal" when exiting this context.

The first tier is equivalent to the lower layers in the case of a handover whereas the second tier is a new component that will reside within the IEEE 802.21 layer (*MIH Function*). The third tier corresponds to the IEEE 802.21 *MIH user*.

When considering this general context-aware services framework, it turns out that the IEEE 802.21 handover decision support is just a special case of a context-aware service. The *MIH user* (i.e. tier three service) registers at the *MIH Function* (i.e. tier two context) for a specific network event (e.g. "network link down"). When this event occurs, the network interface (i.e. tier one sensor) sends an event to the *MIH Function* which transfers this event to the registered *MIH user*. The *MIH user* exploits this information for a context-aware service (i.e. to trigger handover).

Besides handover decision support, this general architecture can support a wide variety of context-aware services.

3. Conclusion

We can conclude from these considerations that it is indeed feasibly to provide a service architecture that supports traditional, topology-unaware, wide-area service discovery and service-aware concepts as well as mobility-motivated, local-access-network-oriented services like hand-over. Integrating these aspects into a single architecture provides the additional benefits of providing "low-layer" information to all types of services. We assume that the efficiency of the architecture will suffice to master the challenges of all the envisioned services. Clearly this is pending a prototypical implementation and performance evaluation.

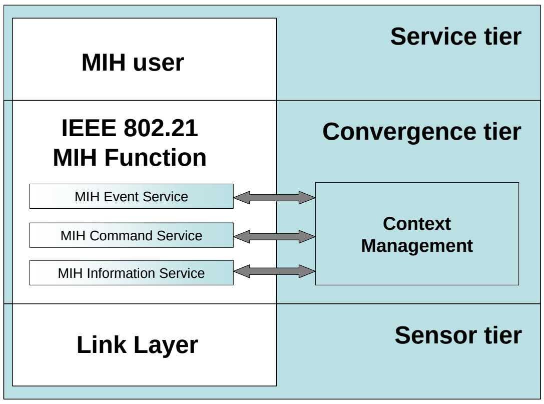

Fig. 3: IEEE 802.21 based context-aware service architecture

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