Ambient Network Advertisements

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***Abstract*— One of the main goals of the Ambient Networks project is to develop mechanisms to enhance the probability of a user to have connectivity, independently of the network access technology. As networks and terminals are supporting multiple access technologies, it becomes increasingly important to quickly select the most optimal access depending on the status of the networks, users and applications, without adding extra burden of manual network configuration on the client or the network side. In this paper the advertising and attachment procedure of Ambient Networks is outlined, focusing on the exchange of Ambient Information Elements. In addition, an example of the whole process is described using WLAN as the underlying access technology. It is shown that the framework provides a multitude of options and that it can be used in networks utilizing a multitude of legacy technologies.**

***Index Terms*—multi-access communication, heterogeneous networks, ambient networking.**

I. Introduction

We see an increasing diversity in wireless communications technologies that are being developed and brought to the market. For instance, global coverage is provided by cellular wide-area mobile communications systems, starting from 2G (e.g. GSM, EGPRS) to 3G (e.g. UMTS, HSPA) and its long-term evolution (LTE). In addition, there is an increasing number of local area networks based on different versions of the WLAN standard IEEE 802.11. Furthermore, metropolitan area networks based on WiMAX will be rolled-out in near future. This diversity in access technologies leads to a change of the wireless ecosystem. Different operators will provide different types of connectivity. Some will embrace multiple access technologies; some will focus on a single access technology. Many will focus only on small geographic areas, like hotspots in city centers, and rely on the wider coverage and user reachability provided by cellular operators. This can lead to a multiplicity of (possibly dynamically changing) business relationships for cooperation between different network providers going beyond the roaming relationships found today. The technological challenges of such an environment is the focus of the Ambient Networks project [1][2][3].

For a mobile user, this new wireless landscape imposes several challenges. The user is frequently exposed to a multitude of available access systems. There are practical limitations on the number of access systems that the user terminal (or user network in case of multiple interconnected devices) can and should connect to. First, the number of radio modems that can be operated simultaneously is restricted by terminal size, cross-system interference and costs. Second, mobile devices are battery-operated, and a large number of connections drain the battery quickly. Thirdly, accessing multiple networks simultaneously is expensive in economic terms. The objective of a user is to profit from the diversity of available access systems, but restrict the number of connections to a few which are best suited. This *access selection* must be achieved in an efficient manner, with limited amount of interactions between the mobile devices and the access systems.

The focus of this paper is on the twin issues of advertisement and attachment in Ambient Networks. In particular, we discuss various options for advertising and also consider how different access technologies can support different advertising mechanisms. Furthermore, advertising use cases based on WLAN are described and analysed.

The rest of this paper is organised as follows. In the next section, the related work is briefly described, followed by an overview of the Ambient Networks approach. The Information Elements that are included in advertisements are presented in Section IV and then different methods for distribution of advertisements are discussed. In Section VI, the realization of AN advertising mechanisms in WLAN environment is described. Finally, we present the main conclusions in Section VII.

II. Related Work

This work extends earlier work on secure and fast network attachment [5] [6] [9], network composition [1][2][5] and access selection [1][2][3][5] within the Ambient Networks project. The problem of determining network capabilities has been described in IETF [12] and in IEEE 802.11u [11]. IEEE 802.21 proposes a media independent information service [10] which is similar to ambient networks advertisements. In 3GPP specifications, advertisements are already defined and included in *system information blocks* [13][14]. These can indicate other cooperating (roaming) networks, and neighbour list information about other access technologies.

III. Approach

Several steps need to be performed before a device has sufficient end-to-end connectivity for its applications. In IEEE 802.11 networks, for example, these steps include the network detection, association and authentication at the access layer, IP address configuration, and default router discovery. Additional steps are required for mobile nodes that move between subnets, or in situations where there is a need to interact with quality of service mechanisms or middleboxes such as NATs or firewalls. The approach taken within the Ambient Networks project is to integrate procedures across different protocol layers. This allows end users to obtain relevant information about the capabilities of different available access systems at an early stage and reduces the amount of signaling.

The Ambient Network Attachment is the generic procedure for setting up a communication channel and a security association for secure control signaling exchange between

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two ambient networks (AN). It is based on the Ambient Network Attachment Protocol (ANAP) [6][5]. In this paper, we focus on a scenario where one of the networks is a mobile user network (in the simplest case a single terminal) and the other is an access network[2]. ANAP enables such a procedure between ANAP end-points in the respective attaching ANs. It also provides the mechanism for distribution of AN Information Elements (IEs) about available network services between control functions, such as Multi-Radio Resource Management (MRRM) and Network Advertisement and Discovery (NAD) [5]. AN advertisements include a number of information elements that contain information necessary for attachment or information related to business issues, e.g. tariffs, offered services etc. This information is required to establish a composition agreement (CA), which is an agreement about the policies of network usage, network cooperation and compensation [5]. In this paper we focus on providing access and network specific information to a user network, so that the user network can determine at an early stage if the observed access network is a potential candidate. This enables the user network to decide what networks to scan for and/or attach to, thereby saving battery resources for scanning and signaling.

IV. AN Information Elements

An AN advertisement may contain a number of Information Elements that contain information necessary for making a decision on the network to attach as well as the attachment procedure itself.

Depending on the underlying access technologies, the IEs may be transferred to the receiver of the advertisement by various means, e.g. in access technology specific broadcast messages (e.g. in WLAN Beacon frames), in ANAP messages or by using other mechanisms for inter-AN communication (e.g. in Generic AN Signaling (GANS) messages [15]). The allocation of IEs to various transmission mechanisms should be done to balance resource usage and quality of service. Note that this balance may be different for different access technologies.

Below are some examples of information that can be sent and received in the AN advertisements.

- Configuration parameters, e.g.
  - IP version, IPv6 prefix
  - Routing information
  - DHCP, DNS server addresses
  - Supported autoconfiguration mechanisms
  - Supported AAA mechanisms
- Cryptographic IDs of
  - ANs
  - User
  - Roaming operators
- Service information
  - Network capabilities, e.g. positioning
  - Supported QoS classes
  - Access type and related service level
  - Payment options

More details about information elements can be found in [5]

[2] In [6][5] also other network attachment cases are considered which are beyond the scope of this paper.

V. Distribution of AN Advertisements

Different protocol layers and link technologies provide different mechanisms for distributing advertisements. Advertisements can be transferred over several different paths depending on the specific use case and the available technologies:

1. Advertisements can be embedded in beacons of the access technology. This option does not support individualized advertisements containing information for a specific user.
2. Advertisements can be sent as specific messages using the addressing of the underlying RAT (Radio Access Technology), e.g. Ethernet broadcast messages. This method possibly supports individual and secure offers, depending on the underlying RAT.
3. Advertisements may be embedded in the ANAP messages.
4. Advertisements may be sent through the normal communication bearer between Ambient Control Space functions. This provides secure and authenticated communication. Note that this option is only available after the attachment procedure.

A. AN Advertisements

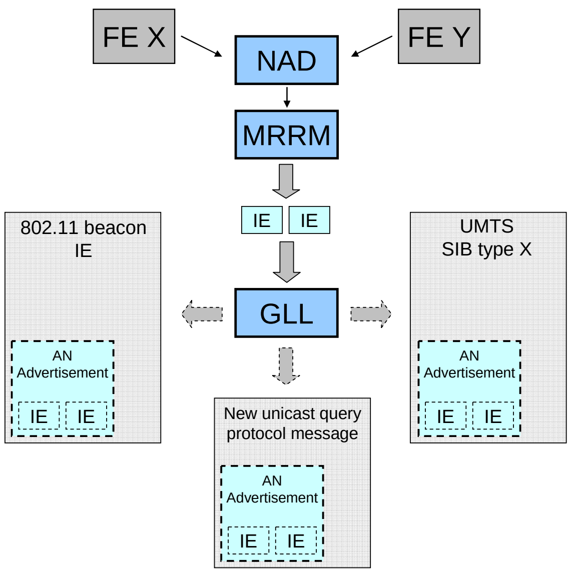

Figure 1: Coordination of AN advertisements

An example for the coordination of AN advertisements is presented in Figure 1. The Network Advertisement and Discovery (NAD) function receives AN Information Elements to be advertised from other AN control functions (referred to as functional entities or FEs), like Composition, Compensation, Policy or Security Domain Management etc. NAD encapsulates the IEs into an AN Advertisement, which it forwards to the MRRM function. NAD and MRRM need to co-operate on the maximum size of the advertisement, as the maximum size and the method of advertising varies between different access technologies. MRRM receives the advertisement and sends it via the Generic Link Layer (GLL) using relevant access systems. A peer GLL entity receives the AN Advertisement and stores the AN Information Elements for the Detected Set of accesses. The AN Advertisement is processed by the NAD-FE and based on FE-specific filters, it distributes AN Information Elements to corresponding FEs.

B. Access Technology Support

It is important to understand how existing access technologies could support the distribution of AN advertisements. Three levels of support are possible: sending the advertisements after the access layer attachment, extending the access layer with support for advertisements or having native ANAP support.

1) AN Advertisements after access attachment

This kind of advertisement requires no changes to existing access systems. Before receiving any AN Information Elements, access layer connectivity is established. After that, AN advertisements can be received via the access layer connectivity. This option has least impact on legacy access system, but it is also least efficient, since connectivity first needs to be established, in order to evaluate in subsequent ANAP and composition procedures, if the connectivity is required (see Figure 2). In this case, however, it may be possible to identify the user and send more personalized or trusted information than in broadcast messages that would be received by anybody.

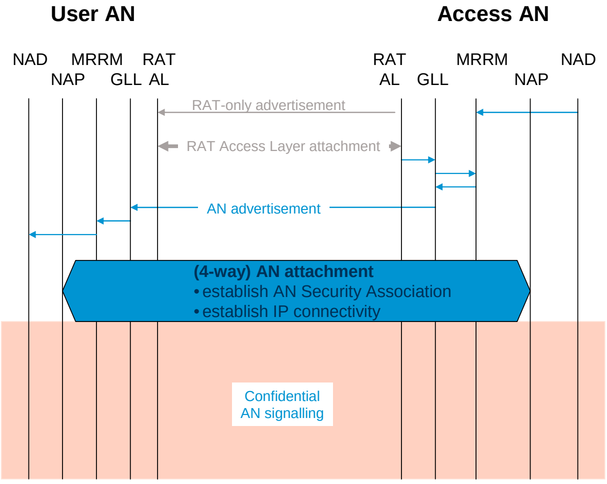

Figure 2: Advertisements after access attachment

2) Extended access functionality

The access layer may be extended to support AN Advertisements. The support can vary between a single flag indicating the support for AN functions, and a mechanism to send complete AN Advertisements in the access layer messages (e.g. beacons). AN Information Elements can be included in access layer beacons or other access layer control messages during connectivity setup. This enables any mobile AN to observe the services, capability and characteristics of an access AN at an early stage, before full network attachment is performed (see Figure 3). This allows to abort a network attachment procedure at an early stage, if an access AN is found to be incapable of meeting the user requirements. This approach requires that access technologies are modified to be able to embed AN Information Elements into access layer beacons or control messages. By broadcasting AN Information Elements, the overhead of the access layer specific beacons increases and leads to a higher signaling cost; at the same time, the effort required by mobile ANs decreases, as they can retrieve significant information by listening to beacons instead of first attaching to a network before receiving further information.

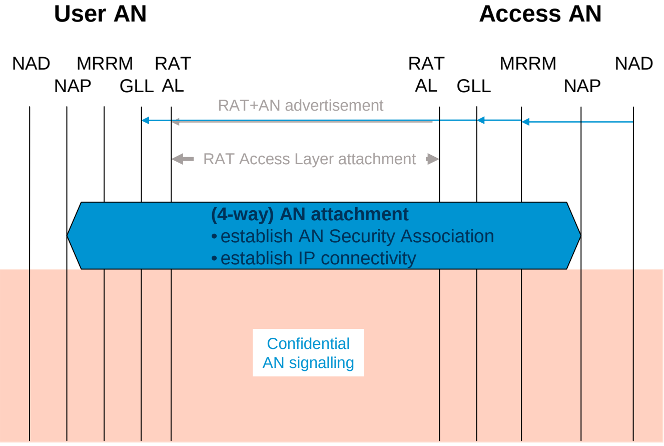

Figure 3: Extended access advertisements

3) Native ANAP Support

The access technology may natively support ANAP, i.e. to use ANAP as the attachment procedure for the access layer. This is the most integrated and efficient option, as there is no need for separate access layer attachment followed by ANAP. The four ANAP messages may be sent over the access layer technology messages, which may also include technology specific settings. As an example, with IEEE 802.11 networks the four messages of ANAP could be bundled together with the WLAN open authentication and association messages. The initial advertisement may be embedded in the WLAN beacon or probe reply frame (see Figure 4).

This approach requires changes to existing access technologies, which imposes the problem of backward compatibility with existing devices and networks. Therefore it is desirable to determine the capabilities of the device or network. If native ANAP support is not provided by the access technology implementation on both sides a fallback to the AN advertisements procedure after attachment (see section V.B.1) is required. If we assume that a network does not support ANAP within the access layer a user device can notice this by the absence of an according indication in the beacon. As a result, the user device automatically initiates a legacy association procedure. If in contrast the user device does not support native ANAP support, it ignores the additional information in the beacon and automatically initiates the normal association procedure. In a sense, ANAP extension is similar to the 802.11i security extension.

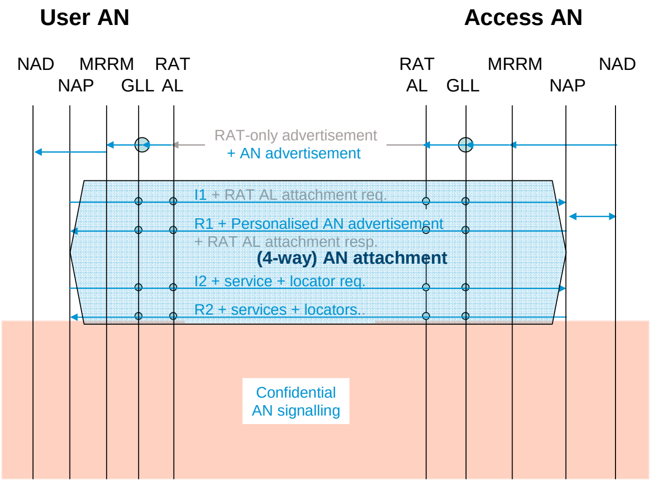

Figure 4: Native ANAP support

C. *Analysis of Current Access Technologies*

There are different limitations and possibilities to provide AN advertisement with the existing access technologies, therefore we have studied the advertisement mechanisms of some of the most prominent ones.

With wired Ethernet, periodic broadcasts of AN advertisements would generate too much network and processing load in the network, as the broadcast interval would have to be really short to have gain, compared to a model where the attaching node solicits an advertisement after a link up trigger from the physical network interface (compare to IPv6 router solicitation/advertisement mechanism).

With WiMAX (802.16), the DL-MAP broadcast management frame would be the most appropriate to carry AN related information. It supports large frames with flexible format.

In 3GPP networks, (UTRAN & E-UTRAN) support for AN advertisements could use the 3GPP System Information Broadcast (SIB) mechanism, which is flexible enough to accommodate any kind of additional information. AN related information would be part of "Core Network System Information" part of SIB1 (in UTRAN) [13][14].

IEEE 802.11 uses a Beacon Management Frame (BMF). Candidate information field in the BMF body is the Capability Information Field. Depending on the WLAN type, it has 11, 8, 6, 1 unused (reserved) bits respectively for the WLAN versions 802.11a, b, g, e. Alternatively, a completely new information field could be added to BMF, which can contain variable length TLV-encoded fields, similar to the security extensions used in 802.11i. If we consider ANAP as a replacement of 802.11i, then the space reserved for 802.11i can be used for AN advertisements thus not causing any extra load into the broadcast traffic compared to a standard secure WLAN network.

D. *Securing AN Advertisements*

A special problem related to AN advertisement which are sent prior to the establishment of a security association, is the capability of the receiver to validate the correctness of the information which is advertised. One way to do this is by having the AN advertisements signed by a trusted third party. A typical example would be a large wide-area network operator that cooperates with a large number of small access providers. Users have a high trust level in the wide-area operator based on a long-term relationship (e.g., a subscription). In contrast, users have a relatively low level of trust with the small access providers to which they have no existing business relationship. The wide-area operator can then take the role of trusted third party for advertisements provided by the cooperating local access providers. The wide-area operator can produce an assertion (signed by its private key) for (some) capabilities and services advertised by the local access provider. A receiver can then validate the received advertisements by decrypting the assertion with the public key of the wide-area operator. For further details see [5].

VI. REALIZATION AND DISCUSSION

In this section, an example of one possible realization of the advertisement and attachment process is presented together with calculations of the resource usage, with the full details available in [4]. We assume that the RAT is standard 802.11b WLAN without any AN-specific provisions.

The modeled process begins with the user AN passively scanning for access points. When an AP is found, the user terminal performs the 802.11 association. Then an advertisement is solicited using WLAN broadcasts. We assume the offer is acceptable and the user AN performs WLAN association, open system authentication and ANAP. Further, a Generic AN Signaling signalling association [15] is setup to enable subsequent Composition Agreement (CA) negotiations. The advertisement simply contains 4 available services and a simple CA negotiation is used where one offer is sent which is immediately accepted. We consider two different scenarios: with legacy WLAN and AN-enabled WLAN, respectively.

Figure 5 illustrates the legacy WLAN case. First, AN1 (the “user AN”) listens to WLAN beacons from AN2 (the “provider AN”). This is followed by the WLAN association procedure. AN1 then requests advertisement from AN2 by sending “AN Advertisement Solicitation Request”. The latter responds with “AN Advertisement Solicitation Reply” message which contains advertising information. This triggers AN1 to execute the attachment handshake, assuming that AN1 infers from the advertisement that AN2 meets its requirements. A succesful attachment may then be followed by the CA (Composition Agreement) negotiation (not shown in the figure).

Figure 6 shows the signalling sequence for AN-enabled scenario. In this case, WLAN beacons are extended to carry additional 56 bytes of AN advertisement data. Furthermore, the WLAN open authentication and association procedures are integrated with the ANAP handshake. In addition, AN2 piggybacks additional advertising information onto the R1 and R2 messages. Note that AN1 can explicitly request the sending of such information via I1 and I2 messages.

For this example, we focus on how long the channel is occupied. This is a simple measure of how much radio resources are used for the advertisement procedure. In addition it avoids the problem of different data rates on the channel. In our investigation we consider no processing delay, and assume an unloaded WLAN system (i.e. there is no contention).

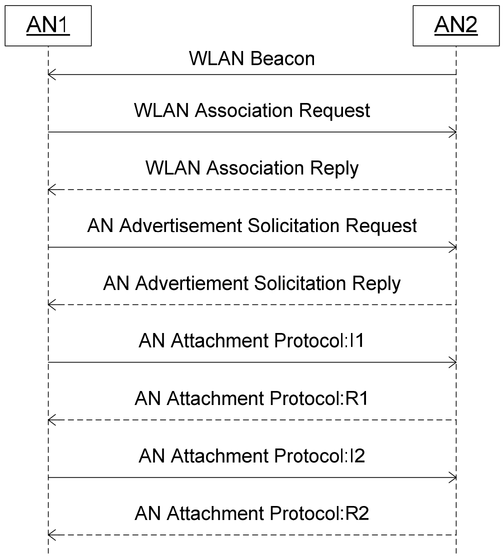

Figure 5: Advertising and Attachment in Legacy WLAN

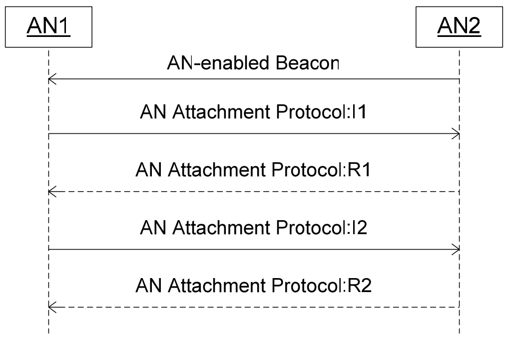

Figure 6: Advertising and Attachment in AN-enabled WLAN

Table 1 gives the transmission time that is required for transmitting the messages of the different stages of the process over the radio channel. For example, the transmission of the WLAN beacon in the legacy case takes up 0.95 ms whereas in the AN-enabled case, 1.4 ms are needed because it contains addition information related to service offerings.

	ANAP for legacy RAT	**ANAP for RAT with AN adv.**
Passive/active scanning	*~600/150 ms [8]*	*~600/150 ms [8]*
Beacon	0.95 ms	1.4 ms
Adv, solicitation and Attachment	7.2 ms	4.4 ms
GANS setup/CA negotiations	6.3 ms	6.3 ms
Sum	**14.45 ms**	**12.1 ms**

Table 1: Time spent in various stages of the advertising and attachment procedure.

In this particular example, the main delay and resource use is due to the legacy layers. This indicates that the results are strongly influenced by the selection of RAT and thus more access technologies should be investigated.

In a more integrated approach, where the service advertisements are allocated to the beacons and all other attachment information is piggybacked in the ANAP handshake, the beacon is extended by 0.45 ms and the total time is reduced to 12.1 ms, equivalent to a 16% reduction. With an extended beacon, a user can determine after listening to the beacon if the access is acceptable or not. Without beacon extensions, users first need to attach and detect access capabilities before they can determine the suitability of the access. This is depicted in Figure 5. We can see that there is a substantial gain in delay for those users that decide after network evaluation not to use an access network. These users can already terminate with the network evaluation 1.4 ms after receiving the beacon when AN advertisements are included in the beacons. Without such AN advertisement support a network evaluation lasts 14.5 ms. For users which choose to accept the access network, the gain is comparatively small (i.e. 12.1 ms instead of 14.45 ms).

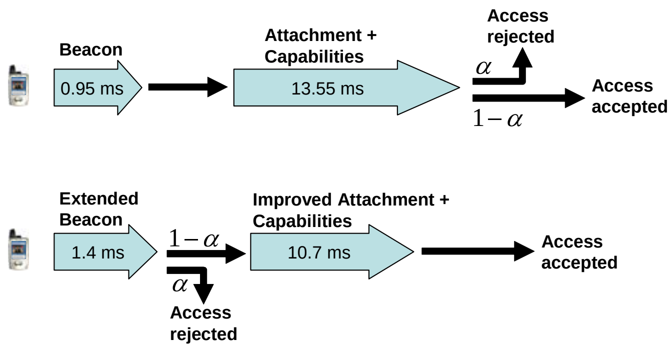

Figure 7: Assessment of access network capabilities without (top) and with (bottom) Ambient Networks advertisements.

In addition to the performance aspects of individual also the system impact needs to be understood. Extended beacons with a beacon interval of 100ms increase the channel occupancy of the beacon from 0.95% (0.95ms/100ms) to 1.4% (1.4ms/100ms). We assume a scenario as depicted in Figure 8: N users are within the coverage of an access, X is the average interval between users trying to validate the access (it depends on e.g. user velocity), and α as the probability of a user rejecting the access.

A gain by integrated network attachment can then be found, when the reduction in channel occupancy due to advertisement and attachment of the N users is larger than the increase in channel occupancy due to the extended beacon:

$$\frac{N}{X}\cdot\left((1-\alpha)\cdot 2.4\text{ms}+\alpha\cdot 13.1\text{ms}\right)\geq\frac{1.4\text{ms}-0.95\text{ms}}{100\text{ms}}.$$

Some numerical examples may be enlightening: In a cell with 20 users and with a beacon interval of 100 ms and a rejection probability of 10% the extended beacon is the better choice for a network evaluation rate X of once every 15 seconds. For a rejection probability of 90% the corresponding number for X is 53 seconds. The numerical examples indicate that the extended beacons are suitable in heavily loaded cells. The main point to note however is that regardless of the solution chosen the extra overhead caused by AN technology is minor.

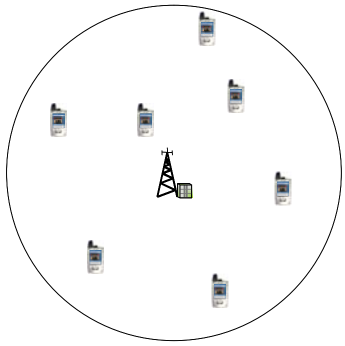

Figure 8: Systems scenario

We can see from the example that the approach of integrating ANAP and AN advertisements with access technology specific methods performs better. From a user perspective it is beneficial to avoid using the air interface and transmitting to save energy. However we can see that the largest part is in the scanning for an AP and after one is found the additional resource usage for performing the complete attachment is minor.

The possibility of the event that a user notices a network or access point and then possibly evaluates it and decides not to use the access depends on the number of available networks, the mobility of users and the policies that govern the behavior of the users. However, even with many networks and quickly moving users, a decision to not use a network more than once every few seconds seems unlikely.

VII. Conclusion

In this paper, the advertising and attachment procedure of Ambient Networks is outlined, focusing on the exchange of Information Elements. In addition, an example of the whole process is described using WLAN as the underlying access technology. It is shown that the framework provides a multitude of options and that it can be used in networks utilizing a multitude of legacy technologies. However, the best allocation of information elements to different stages of the process is still an item for further studies.

It is left for further study to evaluate the overhead and performance of AN advertisements in a wider set of scenarios. For this, the number of users, the number of available networks and user mobility needs to be investigated. It is also required to extend the model to consider the overhead due to channel contention. A further aspect worth investigating is the power consumption for scanning for surrounding networks with and without AN advertisements.

VIII. Acknowledgements

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