

Scenarios for Network Composition in Ambient Networks: a new paradigm for Internetworking

Rui Campos (INESC Porto), Nadeem Akhtar (U Surrey), Carlos Pinho (INESC Porto), José Ruela (INESC Porto), Manuel Ricardo (INESC Porto), Cornelia Kappler (Siemens AG), Cornel Pampu (Siemens AG), Louise Burness (BT), Philip Eardley (BT), Petteri Pöyhönen (Nokia), Paulo Mendes (DoCoMo), Di Zhou (Siemens AG), Marian Angeles Callejo Rodriguez (Telefonica), Jorge Andrés Colás (Telefonica), Linghang Fan (U Surrey), Laura Feeney (SICS), Roger Kalden (Ericsson), Pekka Koskela (VTT), Gösta Leijonhuvud (Ericsson), Klaus Mössner (U Surrey), Janne Riihijarvi (RWTH Aachen), Morten Schläger (TU Berlin) and Brynjar-Age Viken (Telenor)

Abstract

Today connectivity between IP networks can be automatically configured, but the control layers are often not compatible. In the IST Project Ambient Networks, a novel concept for internetworking in the control plane and control sharing, called Composition, is being developed.

This paper describes the composition mechanism and illustrates it by means of scenarios, devoting particular attention to migration issues.

Keywords – *Ambient Network, Ambient Control Space, Ambient Network Interface, Generic Ambient Network Signalling protocol, Network Composition*

1 Introduction

Nowadays, a number of different wireless technologies, such as GSM, UMTS, WLAN, and Bluetooth are available. These technologies have been developed independently of each other and there is no common operation between them, so functions such as seamless handover and multihoming are not supported efficiently. A new research challenge is to overcome these shortcomings, so that in the future we can have surrounding electronic environments adapting themselves to users' needs. These so-called intelligent ambients will require ubiquitous communication, so that devices can communicate with each other, and with

users everywhere and at every time. Characteristics of this communications environment include an ever-increasing range of wireless and wired technologies, and increasing levels of mobility within and of networks, in addition to the mobility of end users. This dynamic environment requires more streamlined configuration and control procedures to achieve the appearance of an ambient communications environment.

The interworking between 3G and WLAN networks presented in [1] is a step towards a better cooperation. However in the current release of 3GPP networks, interworking is limited in accomplishing ubiquitous communication as it achieves only cooperative authentication to enable roaming between the networks. Functionality such as seamless handover or Quality of Service handover are not yet possible. Another solution is presented in [2], where migration of mobile networks towards networks based on the IP protocol (All-IP networks) is defined, thus trying to provide standard access to any network. Here the focus is on data-plane connectivity; this architecture does not propose an automatic mechanism to interconnect networks in the control plane, which is important:

- From a user perspective, users are interested in seamless service support which requires much more than data packet connectivity, such as mobility support, Quality of Service, or security.

- From a service provider perspective, the service provider wants their service to operate without needing to manage the possible changes in underlying communications infrastructure
- From a network operator perspective as there is currently a large overhead in connecting new networks which will limit the way in which dynamic networks can integrate into the communications ether.

On the other hand, automatic connectivity within IP networks is already possible, namely using Dynamic Host Configuration Protocol [6], Dynamic Configuration Link-Local IPv4 Address [7], the IPv6 autoconfiguration procedure defined in [8], and routing protocols like OSPF [9] or BGP [10]; however, the automatic configuration and interconnection in these solutions is only established in the network data plane, while the cooperation between network control planes still has to be configured manually.

In order to allow autoconfigured control-plane interworking, the current mobile networks paradigms must be enhanced. To that end, the IST Project Ambient Networks is developing a new concept for inter-networking, called Ambient Network Composition. This concept assumes that control-plane interworking and control sharing between Ambient Networks create a new composed Ambient Network, and that the creation process is as automatic as possible.

In this paper we describe the network composition concept by using some scenarios, and showing its benefits when used in the context of heterogeneous networks supporting mobility. We also address the migration process of current networks towards an Ambient Network. Thus, in Sec. 2, we introduce in more detail the concept of Ambient Network. Sec. 3 describes network composition, and the degrees of composition defined within the composition framework. In Sec. 4, scenarios to study network composition, and interworking with legacy networks, are given. Sec. 5 presents some

requirements already derived in the IST Ambient Networks project. Finally, the conclusions are drawn in Sec. 6.

2 Ambient Network

An Ambient Network is a set of one or more nodes and/or devices sharing a common network control plane called Ambient Control Space (ACS). When Ambient Networks compose, their control planes cooperate so that the composed Ambient Network appears to the outside world as a single uniform Ambient Network. Well defined access to the ACS is provided to users and to other Ambient Networks through the ASI (Ambient Service Interface) and the ANI, respectively. These interfaces will provide access to any network, including mobile personal networks, through instant establishment of inter-network agreements. The ACS is composed of several Functional Areas (FAs), including the Composition Functional Area (C-FA), the mobility Functional Area, the QoS Functional Area (QoS-FA), and the Congestion Control Functional Area (CC-FA), reflecting different management tasks. These FAs cooperate with each other through the ANI, in order to have overall cooperation between Ambient Networks. It is important to emphasize that the concepts of Ambient Network and Functional Area make no assumptions about whether FAs are implemented in a centralized or in decentralized way.

An Ambient Network has one or more identities by which it can be contacted, and it is able to compose with other Ambient Networks. ANs can be single nodes; treating nodes the same way as networks allows unifying of the Composition concept. The ANI must be supported in all cases and Composition must scale from small sensor nodes to large networks. Figure 1 shows the current structure adopted for an AN. It shows the ACS, the ASI and the ANI, and the GANS protocol used to carry out Composition, Authentication, and other tasks, across the ANI. Furthermore, it presents some of the Functional Areas already defined in the scope of the IST Ambient Networks project, such as

Composition FA, QoS FA, Congestion Control FA, Mobility FA, and Security FA.

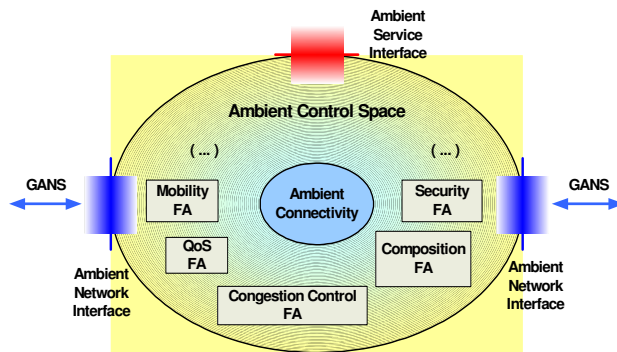


Figure 1. Ambient Network Structure

2.1 Composition Functional Area

The Composition Functional Area (C-FA) is the central control function of an ACS, responsible for Composition related network control and management issues. At this time, there are minimal assumptions about the way C-FA may operate, be implemented, updated or managed, except for its existence. One of the main tasks of the C-FA is to provide decision logic to control the Composition processes based on the related policies, the state of the AN it is controlling and the inputs from other FAs. The C-FA is the control centre from the point of view of network composition and may consult other FAs of the same AN for composition-related issues as well as to delegate tasks to them.

2.2 ANI interface and GANS protocol

The ANI is an open, flexible, and modular interface used by ANs to communicate with each other. This communication may take place either between non-composed or composed Ambient Networks. The former enables ANs to compose while the latter enables composed ANs to exchange information required to maintain the composition. The required addressing information to use the ANI like a contact address of peer ANs may be achieved

dynamically, for example, based on an AN discovery procedure.

If the identity of an AN is not seen from the outside of the composed network it participates in, it also means that its ANI is hidden. The realization of the ANI may vary according to the ACS; for instance, a single ANI implementation may be distributed over multiple physical network elements, or it may be implemented by a single physical network element.

The base protocol used by ANI is the Generic Ambient Network Signalling (GANS) protocol. ANI integrates existing legacy protocols and interfaces as needed, and avoids replacing standard or de-facto protocols, used for instance to exchange routing information or for mobility support. GANS is used for exchanging information currently not sufficiently covered by generally accepted protocols, such as SLA (Service Level Agreement) negotiation and capability exchange.

3 Network Composition

Network Composition is a new architectural concept introduced in Ambient Networks to enable control-plane interworking and sharing of control functions among networks. Composition goes beyond what the Internet and mobile networks can provide today in that interworking is not restricted to basic addressing and routing. Composition enables, for example, seamless mobility management, and improved network and service efficiency. It also hides interconnection details of cooperating networks to the outside.

Different networks may cooperate with each other dynamically or statically for various purposes. To ensure a smooth and seamless cooperation an agreement has to be made among all networks involved. A Composition Agreement is the contract among all Ambient Networks involved in a network composition, including all mandatory and optional rules and policies they agree to follow. It consists of a general section and subsections referring to agreements between individual FAs, e.g. one subsection would be the SLS (Service

Level Agreement) negotiated between QoS FAs. Hence, the structure of the Composition Agreement is modular. A network Composition is the realization of a Composition Agreement that resulted from negotiations via the ANI. It does not require direct physical contact between ANs. Virtual Compositions are possible between ANs that exchange packets via another transport network. Both negotiation of Composition Agreement and its realization are as “plug & play” as necessary and possible.

A new composed network may be created when individual ANs make an agreement to compose. A composed network consists of all logical and physical resources and services each of its members contribute according to the Composition Agreement. Logically a composed network has its own ACS controlling all its resources and communicating directly to the outside with its own identifier and via its own ANI.

Besides Composition Agreements and composed networks, the framework of Ambient Network Compositions defines: a procedure used by individual Ambient Networks to make a new Composition Agreement and to set up the corresponding composed network, a procedure used by an individual Ambient Network to join an existing composed network, a procedure used by members of a composed network to update the Composition Agreement and a procedure used by a member of a composed network to leave that network composition.

Cooperating networks may compose with each other at different degrees, for different purposes. The degree of Composition may influence strongly the contents of the Composition Agreement and the behaviour of the composed network. In the Ambient Network Composition framework three categories of network compositions are identified from the point of view of Composition degrees, i.e. full compositions, partial compositions and no-compositions:

- **Full composition** is a special case of network composition where the composing Ambient Networks merge

fully. The composed network of a full Composition consists of all logical and physical resources of all its members. The ACS of the composed network has full control of these resources since the constituent ANs give up all control.

- **No-composition** is another special case of network composition. Here, there is minimal network cooperation based on loose data exchange between ACSs of different ANs, which is required to enable data communication across network boundaries. There is basically no control sharing among the ANs involved. This kind of network cooperation is typical nowadays in Internet or in cellular mobile communication systems.
- **Partial composition** refers to all kinds of network composition except full and no-composition. This is the typical case of network composition, where all involved individual ANs make a Composition Agreement and contribute a subset of their logical and physical resources to the common composed network.

4 Scenarios

In this section we present three distinct scenarios, in order to illustrate the network composition concept and interworking with legacy networks. Sec. 4.1 and Sec. 4.2 introduce two basic technical scenarios showing the partial composition of two PANs (Personal Area Networks) of different owners, and a no-composition between a PAN and an infrastructure AN. Sec. 4.3 describes a user scenario based on these two basic scenarios, pointing out issues related to interworking with legacy networks and migration.

4.1 Partial Composition of 2 ANs

This technical basic scenario gives a simple example of a partial network composition between two PANs. It shall serve as the basis to understand the concepts related to dynamical partial Ambient Network composition and as a building block for the user scenario presented in Sec. 4.3. Below we

describe the scenario and give an example of the process of getting composed.

Description

Two PANs of different owners with direct radio connections decide to compose with each other to share some documents and equipment. A partially composed network consisting of all shared resources with a dedicated ACS is then created between the two PANs based on a Composition Agreement. Moreover, a new identity is created for the partially composed network. This new identity will be used by other Ambient Networks willing to contact the composed AN.

Process of getting composed

In the following we give a set of possible steps carried out by the PANs, in order to create the new partially composed AN:

1. The two PANs contact each other based on a discovery mechanism for a possible partial composition.
2. There is no other AN involved logically or physically.
3. The Authentication and Authorization procedure is carried out.
4. The Composition Agreement on QoS, Charging and security, etc. is made.
5. A new partially composed network is set up and the related common ACS with associated ANI is created. The Composition Agreement describes whether the ANI will be advertised and accessible from the outside.

Figure 2 illustrates the scenario, depicting the PANs, their ANIs, the new partially composed AN (AN-a-b) and its ANI. This new composed AN can be seen as a virtual network maintained by PAN-a and PAN-b, involving the resources agreed between them in the Composition Agreement; in this case the resources agreed are some documents and equipment.

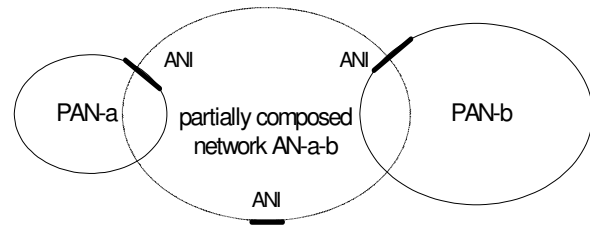


Figure 2. A partial composition between two PANs

4.2 No-composition between a PAN and an infrastructure AN

This technical basic scenario is introduced to give a simple example of a no-composition between a PAN and an infrastructure AN. It is used to describe the cases where ANs contact each other and perform basic control plane interworking without creating any Composition Agreement or composed network, similar to what happens commonly today. Furthermore, it shall be used as a building block for the user scenario presented in Sec. 4.3. Below we describe the scenario and give an example of the process of getting composed.

Description

A PAN moves into the geographical area covered by an infrastructure network and attaches to this infrastructure network by setting up a no-composition. There is no Composition Agreement and no composed network results.

Process of getting composed

In the following we give a set of possible steps carried out by the PAN in order to attach to the infrastructure AN:

1. The PAN and infrastructure AN find each other using a discovery mechanism.
2. The PAN contacts the infrastructure network for attachment, i.e. no-composition.
3. The Authentication and Authorization procedures are carried out.
4. SLA is agreed between the infrastructure AN, and the PAN.

- The PAN attaches to the infrastructure AN. There is no Composition Agreement, no composed network and no common ACS created between the PAN and the infrastructure AN.

Figure 3 illustrates the scenario, depicting the PAN and the infrastructure AN, and their corresponding ANIs, which are used to exchange signaling information to accomplish SLA negotiation.

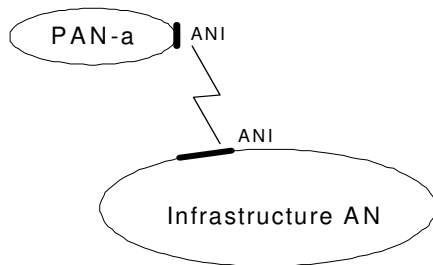


Figure 3. No-composition between a PAN and an infrastructure AN

4.3 Interworking and Migration Scenario

In this section we illustrate an exemplary scenario and use it to highlight different aspects of Ambient Networks. The scenario involves a business worker Veronica, who is traveling on a train en route to a meeting. Veronica owns a PAN that consists of several communication devices, supporting different access technologies (both AN and legacy). During the train journey, she has to keep in touch with her colleagues in her office as well as participate in a pre-meeting discussion via a videoconference session with other meeting participants. Furthermore, she may need to contact her family and friends. The network services are provided by AN and/or legacy networks in order to let her keep in touch while on the move. While in the train, Veronica can use the videophone in the PAN to join the videoconference. She can contact her husband at home using her mobile phone. She can also keep in touch with her colleagues via the webmail service. Veronica wants a good voice quality, and as good as possible video quality with an indicated

minimum level. She expects to go through the entire videophone call while keeping the requested quality level and without having to deal with extra configurations. While moving, there may be handoffs between several access networks. These networks can be AN or legacy networks, and they can belong to different providers and have different capabilities. Sometimes, both AN and legacy networks may be involved in the communication between Veronica and her colleagues or her husband.

The scenario outlined contains many examples of interactions between different Ambient Networks as well between Ambient and legacy networks. These interactions are based on the basic scenarios presented above. The basic scenario used between ANs and legacy networks is no-composition. Partial Composition between two ANs is also used as a basic scenario. For example, Veronica's PAN composes with access ANs.

Technical description

The simplified version of the topology for the exemplary scenario is given in Figure 4, where Veronica's PAN is represented by AN8. During the journey, AN8 handoffs between different access networks that can be Ambient (AN6 and AN9) or legacy (LN7) access networks. The end-to-end path may involve other Ambient (AN2, AN4 and AN5) or legacy (LN3) networks. LT0 may represent Veronica's husband while AN1 may be the office Ambient Network.

While moving, Veronica's PAN may decide to establish a partial composition with access-ANs to obtain the required service with satisfactory quality. It can also decide to establish a no-composition with a legacy network via an interworking unit. In this case, a SLA can be negotiated between Veronica's PAN and the interworking unit in the legacy network to set the QoS and trust levels. The interworking unit can also translate the SLA into a form that the legacy network can understand. In some circumstances, there can be legacy networks on the data path between Veronica's PAN and her colleague's AN, such

as the data path between AN8 and AN1. In this case, the interworking units must perform the necessary mapping between ANs and legacy networks.

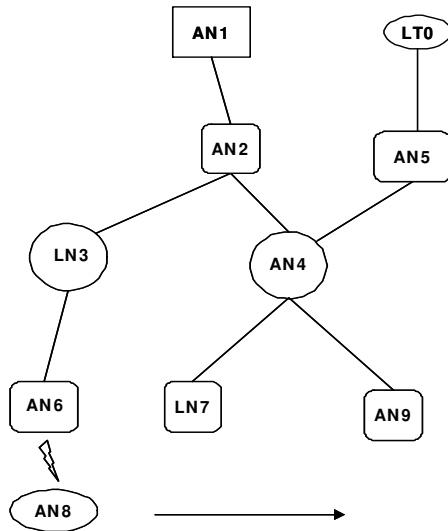


Figure 4. Topology of the scenario

If Veronica's PAN wants to compose with AN1, it should establish connectivity with the neighbor access-AN (AN6). By using its ANI and GANS, Veronica's PAN discovers AN6, and then negotiates a Composition Agreement with it. This Composition Agreement includes an SLA and is made on the basis of the business relationship between both AN8 and AN6. AN6 and AN8 undergo a partial composition in accordance with this Composition Agreement and then AN8 is able to get communication services with a specific quality level. Now, LN3 is a legacy network on the path between AN8 and AN1. There is no Composition between LN3 and the partial composed AN (AN6-AN8). Interworking units, which can perform necessary mapping between ANs and legacy networks, will be used; they can be located in either AN or legacy networks. Here we assume interworking units are located in the legacy networks. In order to set the QoS and trust levels and use the network resources of the legacy network (LN3), the SLA is negotiated between LN3 and the composed AN (AN6-AN8). It is assumed that there is an ANI between the partial composed AN (AN6-

AN8) and LN3's interworking unit. It is noted that LN3's interworking unit can translate the SLA into a form that the legacy network can understand. For example, the QoS mapping between AN QoS class and legacy network QoS class will be performed. Only after SLAs are agreed between all the networks on the path AN8-AN6-LN3-AN2-AN1, AN8 and AN1 may communicate each other with satisfied QoS.

During the journey, AN8 moves and the next available access network is a legacy network (LN7). In order to keep the QoS levels during and after handovers, AN8 should negotiate SLA with LN7 with the help of the interworking unit while keeping the partial Composition between AN8 and AN6. After SLAs are agreed between all the networks on the path AN8-LN7-AN4-AN2-AN1, Veronica's PAN (AN8) can seamlessly switch to the new path with satisfied QoS level. Similarly, when AN8 wants to handoff to the next access network AN9, it will first negotiate a composition agreement and then form a partially composed network with AN9.

The scenario described occurs in present day networks too and solutions have been proposed to ensure smooth interworking between different network elements. The Ambient Network concept aims at elevating interworking to a new level using network composition. In the user scenario above, we find multiple instances where Ambient Networks compose with each other for improved network and service efficiency. For example, AN9 and AN4 may compose in order to provide better end-to-end QoS support. Similarly, if two adjacent access ANs compose, this can help in providing better mobility support. When there is a handoff, new SLAs need to be setup. Hence, dynamic SLAs can play an important role in enabling mobility-aware QoS support. Interworking with legacy networks is crucial because not all future networks will be Ambient Networks. The provision of 'no-composition' is very useful in such cases because it enables Ambient and legacy networks to interwork in order to make use of

the benefits of network composition. Furthermore, such interactions constitute the first step in the path towards the eventual migration of legacy networks to Ambient Networks.

5 Requirements

In the IST Ambient Network project we have been deriving several requirements for AN, Composition and Functional Areas, ANI, GANS, and on migration, using technical scenarios, like those presented in Sec. 4.1 and Sec. 4.2. Requirements mostly express functionality expected for the respective entity. Next, we will focus on requirements for AN, ANI, and migration. We highlight those we think that are the most important ones:

1. *All entities must have an identity* – any AN entity that is involved in some negotiation (e.g. ANI, ACS and each FA) must have an identity that can be used to refer to that entity. Where necessary, this identity must be able to be translated into an address for a communication endpoint.
2. *AN discovery mechanism must be supported* – if an AN does not know the contact address of other AN, it may run the AN discovery procedure, to find valid contact addresses, and provided FAs of surrounding/nearby ANs.
3. *ANs must be able to exchange Functional Area control information via ANI.*
4. *Then, ANI shall enable control data communication both between ACSs in different ANs and internally within a composed network.*
5. *Composed ANs must be able to hide the AN identity, ANI, and ACS of their constituent ANs* – after composition, the composed AN must be able to hide the identity, ANI, and ACS of member ANs, if it is instructed to do so as part of Composition Agreement. This requirement implies, for example, that the composed AN must not expose such information during AN discovery.

6. *Composition should be “plug & play”* – this requirement means that the Composition process should, in general, be automatic and not require direct user interaction.
7. *Migration should be considered from the perspective of all involved parties* – perspective from users, equipment providers, network operators, service providers, and governmental regulatory bodies should be taken into account when defining a migration step in order to assure that it benefits at least one player. Moreover, possible disadvantages for other players should be studied to avoid (conscious or not) unsuccessful migration steps.
8. *Migration should be incremental and of appropriate “granularity”* – one critical issue seems to be to getting the right level of “granularity”; too small and the migration will seem pointless, too big and it may seem daunting. It seems important to focus on the particular perspective of the party that is migrating (user, service provider, etc.).

These requirements and additional ones derived in the IST Ambient Network project will serve as the basis to design the ANI, specify the GANS protocol, understand the most useful way to accomplish the migration from legacy networks to ANs, and to define the architecture and implementation for an Ambient Network.

6 Conclusions

In this paper we presented a new network vision called Ambient Network, and the concept of network composition, enabling cooperation and interworking between networks' control planes. We illustrated this new concept by means of basic scenarios and a user scenario. We argued that Ambient Network Composition is a crucial concept for future mobile networks, providing the means to dynamically and automatically establish SLAs, and seamless mobility management, for example, in a fast and efficient manner. We also focused on the issues related to the

migration of current networks to form an Ambient Network, and interworking between ANs and legacy networks using interworking units.

References

[1] 3GPP TR 22.934, “Feasibility study on 3GPP system to Wireless Local Area Network (WLAN) interworking (Release 6)”, v 6.2.0, September 2003

[2] H. Yumiba, K. Imai and M. Yabusaki, “IP-Based IMT Network Platform”, *IEEE Pers. Commun.*, vol. 8, no. 5, October 2001, pp. 18-23

[3] D. Clark, J. Wroclawski, K. Sollins and R. Braden, “Tussle in Cyberspace: Defining Tomorrow’s Internet”, in *Proc. ACM Sigcomm 2002*, Pittsburgh, PA, USA, August 2002

[4] D. Clark, K. Sollins, J. Wroclawski, and T. Faber, “Addressing Reality: An Architectural Response to Real World Demands on the Evolving Internet”, in *Proc. ACM Sigcomm FDNA 2003 Workshop*, Karlsruhe, Germany, August 2003

[5] Norbert Niebert, Hannu Flinck, Robert Hancock, Holger Karl and Christian Prehofer, “Ambient Networks – An Architecture for Communication Networks Beyond 3G”, *IEEE Wireless Communications*, vol. 11, no. 2, April 2004, pp. 14-22

[6] R. Droms, J. Bound, B. Volz, T. Lemon, C. Perkins and M. Carney, “Dynamic Host Configuration Protocol for IPv6 (DHCPv6)”, IETF RFC 3319, July 2003

[7] Stuart Cheshire, Bernard Aboba and Erik Guttman, “Dynamic Configuration of Link-Local IPv4 Addresses”, IETF Internet draft, draft-ietf-zeroconf-ipv4-linklocal-14.txt, March 2004, work in progress

[8] S. Thomson, T. Narten, T. Jinmei and H. Soliman, “IPv6 Stateless Address Autoconfiguration”, IETF Internet draft, draft-ietf-ipv6-rfc2462bis-00.txt, February 2004, work in progress

[9] J. Moy, “OSPF Version 2”, IETF RFC 2328, April 1998

[10] Y. Rekhter and T. Li, “A Border Gateway Protocol 4 (BGP-4)”, IETF RFC 1771, March 1995

[11] Anton Nijholt, Thomas Rist and Kees Tuijnjenbreijer, “Lost in Ambient Intelligence?”, in *ACM Conference on Human Factors in Computing Systems*, Vienna, Austria, 2004, pp. 1725-1726