Examining a key topic in the ASCOT project – address management in moving hotspots

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***Abstract*— In this paper we provide an overview of the ASCOT project and present intermediate results on investigations concerning address management. ASCOT considers managed vehicular networks, i.e. moving networks attached to public transport vehicles that provide network connectivity to its passengers. We briefly describe how ASCOT positions itself among other projects and activities that focus on moving network aspects. We consider addressing: the pros and cons of the various options for the addressing of end user terminals – including a brief discussion of the relevant end user requirements and the impact on mobility management.**

TERMINOLOGY

MR: A Mobile Router that changes its point of attachment to the ground network. This is the router that provides connectivity between the portable node and external IP networks, e.g. the Internet.

PN: A Portable Node is user equipment with one or more network interfaces. This may be a Mobile Node (MN), which is lightweight and has a wireless interface, or it may be a fixed node that is part of a moving infrastructure.

VN: The Vehicle Network is a special type of moving network attached to a public vehicle and provides managed access to customers.

GN: A Ground Network delivers packets between the VN and an external IP/Internet network[1]. It provides wireless connectivity to the MR.

I. INTRODUCTION

ASCOT (Architecture for Self-Contained mOving neTworks) is a collaborative project between Siemens, BT Exact and Kings College London that focuses on Vehicle Networks (VNs). These are networks that provide local and global network connectivity to vehicle passengers.

A moving network is one in which a number of nodes in a fairly stable topological relation with each other[2] move together with respect to the ground network. This is the area of research of the IETF's NEMO working group[3] (Networks in Motion). The VN is a special, simplified, type of moving network because there is neither nesting (mobile networks within mobile networks) nor ad hoc support (this means for example that the trust relationship between nodes is managed by the VN). Despite these simplifications, we can identify a number of significant business scenarios for this type of network, particularly related to users on long distance plane, train or boat journeys. We expect that VN is more likely to be used where users have significant time to, for example, web browse or settle to work. This shows similarities with the WLAN hot spot scenario but includes the aspects of network movement. The VN will also be of interest where coverage may not be consistently available based on a single technology - here a multi-homed MR could hide the complexity of inter-technology handover from the user. We also consider that the services will be more popular on vehicles with many users - both because there is a greater possibility to share an expensive, limited bandwidth connection to the Internet, and because local services will be stronger with a larger user base. The use of a VN is also of benefit to the ground networks as it hides the problem of multiple, simultaneous device handovers. Use of a managed network in this scenario ensures that the cost of local services, such as information services, may be recouped by the VN. The managed network aspects also makes security and trust relationships stronger and easier for the user.

This paper focuses on the key problem of how to allocate IP addresses to the user equipment so that users can communicate efficiently both locally and with the broader Internet. The addressing model impacts many aspects of the system, for example what services can be supported and how the MR can use multi-homing to minimise service disruptions due to patchy coverage of ground networks. In this paper, we identify four main

[1] Although we call it a 'ground' network, note that the GN may be a satellite system.

[2] There is no reason why these devices are not mobile at the sub-network layers, for example using WLAN the nodes could move randomly along the train.

[3] Formerly called the MONET (Mobile Networks) WG

options for the addressing of the PN, and analyse these against the set of requirements derived from the business drivers for this service.

II. RELATED WORK

Beside ASCOT there are a number of other projects investigating aspects of providing connectivity to networks on-board vehicles. However, we believe that the scope of ASCOT is more pragmatic than other similar research projects, with our work driven by business model requirements and a goal to provide solutions that could be deployed near term but optimised in the future as GNs capabilities become more advanced. The rest of this section outlines the related work.

- IST BRAIN [1] and MIND [2] investigated an all IP mobile network, which was later extended to include ad hoc networks and vehicular networks. The Vehicle Network (VN) scenarios were considered in terms of possible deployment cases and technical aspects of mobility management, such as handover and context transfer. Preliminary solutions have been presented, but these lack the verification against business models and operator / user requirements. The scope of the problem considered within MIND is a useful input to the ASCOT work, with a number of working assumptions being carried over between the two projects. ASCOT aims to take the solutions developed within MIND and apply the results to a broader scenario where the GN is not only a MIND network but also includes other types of access network with differing capabilities. This in turn introduces a number of new facets to the problem that are considered within our project, such as an extended AAA model and additional multimode operational aspects (where multimode refers to devices with multiple interfaces based on multiple technologies).
- IETF NEMO [3] is currently investigating addressing solutions for moving networks based on Mobile IP support. The network under consideration is more complex compared to the approach taken in this project since NEMO supports the nesting of moving networks. NEMO solutions could be optimised for our purposes by avoiding the issue of nested moving networks. Preliminary work has started within NEMO on related issues such as AAA in the form of specifying requirements and issue capture, some of which have been drawn into the ASCOT activities. However, other aspects within the scope of our project, including multimode operation aspects, security QoS and service implications have not yet been considered.
- IST SUITED [4] and successor FIFTH [5] investigate multimode devices to provide ubiquitous coverage for users via satellite, cellular and WLAN technologies. It includes solutions to handle mobility, using Mobile IP, and end-to-end QoS, but makes a number of assumptions about the characteristics of the ground network infrastructure and associated business models that are not compatible with the ASCOT scenario. The work was extended to include ubiquitous coverage for train based VNs, by looking at coverage in black spots such as tunnels via WLANs attached to a satellite network. This latter work is not in the scope of our project. SUITED and FIFTH have not considered aspects such as security, AAA and local services .
- IST DRIVE [6] and OVERDRIVE [7] consider multimode devices operating in a network with optimised radio resource management techniques as well as mobility and QoS support. The solution utilised cellular, WLAN and digital broadcast radio technologies, and assumes IPv6, Hierarchical Mobile IP, and the presence of specialised devices in the GNs to support radio resource management coordination. The multimode device considerations and interface selection aspects are directly relevant to the ASCOT work, and will be re-used where possible. However, it is not clear whether the mobility and QoS solutions are equally as applicable given the different timescales assumed by each project. Aspects such as security, AAA, addressing and routing for vehicular networks will be monitored for inputs.

It is clear that there are aspects to the ASCOT problem that have not been considered within other related projects and these are the main focus of our investigation. However, we acknowledge that we have learned and re-used ideas from these other projects in order to help scope the problems considered within our project.

III. ADDRESSING IN ASCOT

In this section we present our intermediate analysis about one of the key aspects for an ASCOT solution: addressing for the PNs. One of the reasons for highlighting addressing is to show the technical implications of the requirements.

A. ***Requirements***

The following key addressing requirements are derived from the user business perspective developed for VNs. These requirements are selected for their influence on the technical solutions:

1. **Transparency of VN mobility**: When the MR moves onto a new point of attachment its IP address changes. This should not impact the address assigned to the PN, in order to prevent signalling bursts from the PNs to update active session and reachability state in the network. Within ASCOT it is assumed that MRs will handover between GNs possibly based on different technologies due to coverage and cost issues. For example, [8] illustrates the intermittency of satellite coverage along a railway track, where WLAN or cellular technologies could be utilised to provide alternative connectivity. These issues are also being considered within FIFTH project [5].

2. **PN global reachability support**: Some users will require support for PN terminated calls, which implies that there is some global reachability information within the network that correspondents can use to determine what IP address to initiate a session with. Note, however, that this does not automatically imply that the PN must have a global IP address, but some way to support the installation of reachability state in the network must be provided by the VN (see addressing option 3 below).

3. **Diverse address support**: Some users will want access based on IPv4, whilst others may require IPv6 access. In addition, PN addresses do not necessarily belong to the same subnet, for example, if some nodes are using their home address. The VN should be able to manage addresses of different types.

4. **Local Services support**: The VN is expected to provide a diverse range of local services, such as route information, timetable information and PN-PN communication. In order to support this efficiently, it is useful to have IP addresses allocated to the PNs that allow local communication using standard IP or link layer routing.

5. **Minimal PN functionality**: A goal of the VN is to support as many users as possible. Requiring complex software upgrades on PN equipment is not compatible with this goal.

B. *Discussion on Addressing Options*

This section presents technical implications of various addressing options and an overview of the extent and manner in which they comply with the requirements. There are four main options for PN addressing:

Option 1: Address from Ground Network

Option 2: Address from Mobile Router's Home Network

Option 3: Address from Mobile Router's Private Network

Option 4: Portable Node's Home Address

Each addressing option has an associated Figure. Table 1 explains the abbreviations used in these figures.

Abbreviation	Abbreviation explanation
IPgn	IP address assigned from the GN
IPcn	Correspondent node's IP address
IPmr	IP address belonging to a subnet of the MR's home network
IPha_MR	MR's home agent IP address
IPvn	Private IP address
IPhoA	PN's home IP address

TABLE I. ABBREVIATIONS USED IN THE FIGURES FOR THE FOUR ADDRESSING OPTIONS

1) *Option 1: Address from Ground Network:*

The GN delivers an address prefix, or set of addresses, to the VN, which the MR can then allocate to attaching PNs. This means that from a Correspondent Node's (CN's) perspective, a PN appears to be connected to the GN. With reference to the above requirements, this option has the following characteristics:

Transparency of VN mobility: The IP address is dependent on the GN, and therefore MR handovers result in an IP address change at the PN. Where the MR is multi-homed, IP address allocation to PNs becomes more complicated since the PN address should reflect which outgoing MR interface the traffic should be sent over. For a PN, changing outgoing MR interface looks the same as an MR handover, basically both result in an address change at the PN.

PN reachability support: The VN assumes that the address allocated to the PN is globally reachable, and therefore does not implement any complex middlebox device discovery or address translation functionality. If the GN has not allocated a globally reachable address, it is either up to the PN to discover this and propose an appropriate address in control signalling, or the GN has to provide address mapping functionality to support globally reachable PNs.

Diverse address support: The support for diverse addresses is limited to the capability provided by the GN. Therefore, it is assumed that the GN expects the VN to support whatever address(es) it allocates.

Local services support: Depending on whether the GN has allocated a prefix or just a set of IP addresses to the MR, local services may be supported within the VN and standard IP routing can be provided to route traffic within the VN.

Minimal PN functionality: Since the PN is exposed to IP address changes of the VN, if session continuity is required the PN must provide handover support functionality, such as Mobile IP. Also, the PN is exposed to the GN IP version differences, and may therefore have to support dual stack transition mechanisms.

The main drawback of this option for the ASCOT scenario is that a VN handover is exposed to the PNs and requires additional complexity to support session continuity and global reachability (eg PN sends mobile IP message). Extra functionality is also required if the PNs and GN are running different versions of IP.

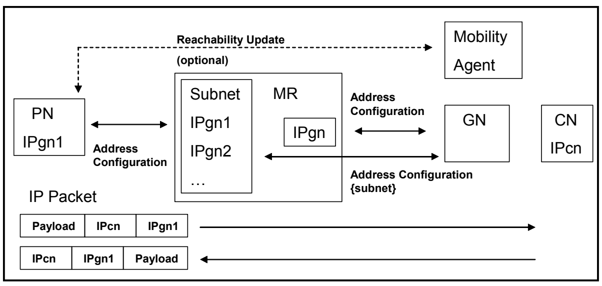

Figure 1. Address from Ground Network

2) Option 2: Address from Mobile Router's Home Network:

The MR has an associated home network, which allocates a subnet to the MR to use for address allocation to PNs. This subnet could be statically configured on the MR, or dynamically allocated when the MR establishes contact with the home network to inform it of its current, reachable IP address. Data arriving at the home network for the VN subnet is tunnelled towards this MR "care-of address" allocated by the GN. The MR may run Mobile IP (MIP) or may utilise VPN technologies to maintain its location during mobility. The former, with a bi-directional MIP tunnel, is also the solution being considered within the IETF NEMO WG [3]. Option 2 supports several of the requirements well:

Transparency of VN mobility: VN mobility is transparent to the PNs since their allocated address is independent of the GN.

PN reachability support: Similar remarks apply as those for the PN reachability support in Option 1.

Diverse address support: Support for diverse addresses is not possible, since PN addresses are expected to belong to the prefix allocated by the VN's home network (unless there is dual stack capability in the VN and the VN's home network).

Local services support: Local services are supported since all PNs share a prefix, and standard IP routing can be provided to route traffic within the VN (although this assumes a single IP version support within the VN).

Minimal PN functionality: The characteristics of the GN are hidden from the PN. However, unless the VN is able to support both IPv4 and IPv6 simultaneously, some PNs may have to provide transition mechanisms in order to access the VN services.

The option requires a 'MR home network'. This should be easily met since it is expected that most operators of a VN will already be operators of public WLAN hotspots,; it also allows them to offer common services and utilise a common billing system, for example.

The main drawback to this option is the tunnel between the MR and its home network, and in particular double tunnelling when the PN uses mobility mechanism as well (traffic is tunnelled from the PN's home agent towards the MR's HA, where it is again encapsulated for forwarding to the PN). There may be considerable inefficiencies from the encapsulation overhead and the long-winded packet forwarding path.

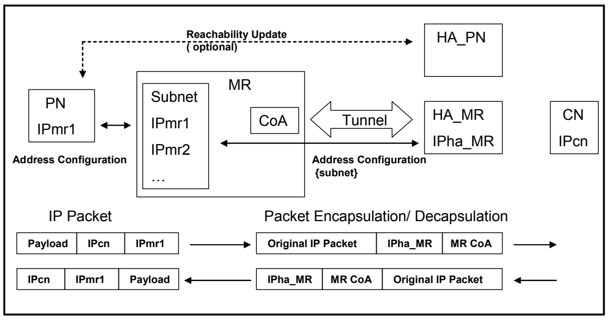

Figure 2. Address from Mobile Router's Home Network

3) Option 3: Address from Mobile Router's Private Network:

The MR provides addresses to PNs from a pre-configured private address space. This option implies the use of a NAT (Network Address Translator) at the MR, to translate from the PN's private address (used within the VN) to a globally reachable address allocated by the GN. There are many different variants of this solution, depending on the type of NAT[4].

Transparency of VN mobility: As for the previous option, the IP address allocated to the PN is independent of the GN, and therefore does not change as the MR hands over.

PN global reachability support: A PN's IP address is private to the VN. Therefore extra complexity is needed so that either the PN or the network provides reachability by mapping the private address onto the globally reachable address. If, for example, the PN is globally reachable at its SIP URL, then the MR must intercept SIP register messages and translate the IP address as appropriate. Alternatively, the PN may discover what IP address to use via mechanisms such as STUN [10] – but when the VN moves and the MR's address changes, the PNs must know to update reachability state within the network.

Diverse address support: This issue depends on the type of solution and address prefixes implemented in the VN.

Local services support: VN internal communication support is good if all addresses allocated to PNs have the same prefix.

Minimal PN functionality: Given that there are a number of ways to support PN reachability in this scenario, the complexity required within the PN depends on the solution chosen and what support is provided by the network.

The main drawback of this option is the inability to easily support PN reachability, if this is seen as a key service that users wish to use, particularly when the VN moves. NATs in general require complex transition functions, if IP address information is reflected in higher layer messages.

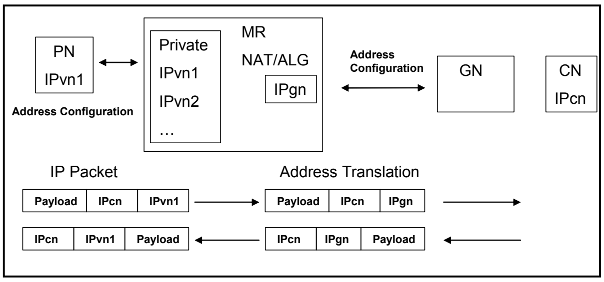

Figure 3. Address Prefix from Mobile Router

[4] For example whether it is a stateless or stateful NAT, and whether it is a NAT or NAPT (Network Address Port Translator). In addition and depending on the applications used by PNs, ALG (Application Level Gateway) functionality might be needed.

4) *Option 4 Portable Node's Home Address:*

The PN continues to use its permanent IP address within the VN, i.e. its normal "home" IP address.

Transparency of VN mobility: The PN IP address is not dependent on either the VN or the GN, and as such VN IP address changes are transparent to the PN.

PN global reachability support: The main reason for the device to want to use its home address is to maintain reachability in the network. However, in order to achieve this, support is required within the network to route the traffic to the PN's current location. This can be achieved in a variety of ways including SIP registration or dynamic DNS.

Diverse address support: The VN must support diverse IP addresses.

Local service support: Since PN addresses will be from a diverse set of prefixes, internal VN communications will require additional complexity within the MR to route traffic correctly.

Minimal PN functionality: Depending on how reachability aspects are provided for this solution, the PN may have to support additional mechanisms to support reachability signalling such as middlebox discovery mechanisms (see [10]).

The main drawback to this solution is the additional complexity required in the VN (and potentially the external network) to support diverse address prefixes and to support global reachability.

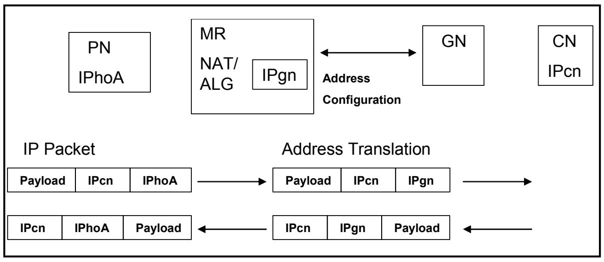

Figure 4. Portable Node Home Address

C. *Summary of Addressing Options*

Table 2 shows a comparison between the four addressing options and the identified requirements.

Requirement\Option	1	2	3	4
Transparency of VN mobility	N	Y	Y[5]	Y
PN global reachability support	Y	Y	N[6]	Y
Diverse address support	N	N	Y/N[7]	Y
Local Services support	Y	Y	N/Y	N
Minimal PN functionality	N	Y	Y	Y

TABLE II. ADDRESSING OPTIONS AND REQUIREMENTS

[5] PN may have to be aware of mobility in order to correctly update reachability state in the network.

[6] But can be enhanced so that this is possible by either adding complexity in the PN or within the VN

[7] Depends on used private address space of VN

It should be noted that compliance with the requirements could be achieved using various technical solutions. The exact choice and details of the solutions would depend on issues such as the existence of VN's home network and the location of the necessary complexity in the network (e.g. MR or home network).

IV. CONCLUSIONS

Currently an increasing number of research activities can be detected that consider the technical field of moving networks. Whereas several of these projects aim to cover aspects of potentially complex 4G network architectures arising from ad hoc network structures, the ASCOT project attempts to take a straight forward, more pragmatic approach. Based on the definition of service requirements and business models for public vehicular networks we intend to provide concepts and mechanisms for a solution that can be deployed in the near future but still support the evolutionary path towards 4G, as Ground Networks are extended with new IP-based capabilities. We recognized that the address allocation mechanism for portable nodes is one of the key issues to be solved for Vehicle Networks. We identified four different addressing options and described these in terms of our ongoing investigations.

The evaluation of the addressing options shows that none of the identified mechanisms completely satisfies the list of proposed requirements. The selection of the appropriate option or combination of options depends on a prioritisation of the requirements to determine which are the most important to meet, and where the complexity of the solution is best located, the VN, the GN or a VN home network. It is clear that the addressing mechanism has considerable impact on other technical aspects of the solution, for example handover, context transfer and multimode MR operation.

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