Proceedings of 7th International Conference on ITS Telecommunications (ITST 2007), pages 375–380, Sophia Antipolis, France, June 2007

NEMO meets VANET: A Deployability Analysis of Network Mobility in Vehicular Communication

Roberto Baldessari[1], Andreas Festag[2], Julien Abeillé[1]

[1]NEC Europe Ltd., Network Laboratories, *baldessari@netlab.nec.de*, *abeille@netlab.nec.de*
[2]NEC Deutschland GmbH, *festag@netlab.nec.de*

***Abstract*— The document analyzes the deployability of approaches for network mobility (NEMO) in wireless vehicular ad hoc networks (VANETs). The vision for VANETs is road safety and commercial comfort applications enabled by short-range wireless technology. For a potential integrated solution of VANETs and NEMO, referred to as 'VANEMO', we consider a deployable system architecture and define requirements from a holistic view, taking into account economic, functional, and performance aspects. Next, we regard the vehicular network as a conventional mobile ad hoc network (VANET as a MANET), generalize possible solutions and classify them into two comprehensive approaches: MANET-centric and NEMO-centric. We analyze the two approaches with respect to the VANET specific requirements. We conclude that the MANET-centric approach meets the VANET functional and performance requirements better than the NEMO-centric approach.**

I. Introduction

Vehicular communication is regarded as a key technology in improving road safety. Various efforts (VII [1], C2C-CC [2], InternetITS [3]), and standardization bodies (IEEE [4], and more generally ISO TC204 [5]) are currently developing a technology based on IEEE 802.11 wireless LAN. While safety is the main focus, mobile infotainment applications are expected to enhance the comfort of driving and traveling. Many infotainment applications require access to the Internet, whereas safety applications typically use direct and local communication among neighboring vehicles ('information processed and consumed where generated').

When considering vehicles as communicating mobile nodes, two existing and independently-developed technologies are combined – IP mobility solutions and vehicular ad hoc network (VANET) routing protocols. IP mobility solutions are widely accepted and currently seem to be the only technologies providing global Internet reachability of nodes and session continuity on the move, without the need for new and specific applications. VANET routing protocols provide wireless multi-hop communication among highly-mobile vehicles in a fully distributed manner.

A further aspect of vehicular communication is that every vehicle can have a set of either built-in or portable communication devices, that form a network that changes, as a unit, its point of attachment to the Internet and thus its reachability in the topology of the infrastructure network. VANETs therefore seem to be a natural use case for the deployment of network mobility concepts, as studied by the IETF working group *Network Mobility* (NEMO[1]). Compared with solutions for IP mobility of single mobile terminals such as Mobile IPv6 [7], NEMO BS provides IPv6 mobility for entire moving networks. The main benefits are: (i) Handovers signaling for all nodes in the mobile network can be aggregated by an entity called *Mobile Router*, resulting in reduced signaling overhead, (ii) NEMO shields the nodes in the mobile network from the movements and thus enables the use of devices that are not provided with any mobility support but with a standard IPv6 protocol stack.

Being designed for mobile networks with single-hop connectivity to a network infrastructure (e.g. trains, airplanes), NEMO BS alone does not provide connectivity over multi-hop, intermittent access to the infrastructure. For this purpose, NEMO BS has to inter-operate with a VANET routing protocol. In this kind of integrated solution, NEMO would provide session continuity and global reachability for a mobile network in a vehicle, whereas VANET routing would handle the communication among vehicles and road-side access points. Studies about NEMO in VANETs are in a very early stage and ready solutions that effectively combine these technologies covering the automotive use cases do not exists. However, it is worth reviewing existing approaches for integration of general mobile ad hoc networks (MANETs) and NEMO. An analysis of these existing solutions reveals whether the requirements of vehicular communications justify the development of 'VANEMO', a VANET-specific solution for integration of NEMO concepts.

In this paper we:

- Describe scenario, system architecture and requirements of vehicular communications for integration of NEMO, paying particular attention to realistic and deployable systems (Section II and III),
- Classify possible approaches for integration of MANETs and NEMO adopting the terms MANET-centric and NEMO-centric introduced in [8] but generalize them with respect to the roles of these protocols (Section IV),
- Analyze approaches with respect to the defined VANET requirements (Section V),
- Derive from the analysis fundamental features requested for future integrated solutions (Section VI).

[1]In the rest of the paper, we use the abbreviation *NEMO* when referring to the general notion of network mobility and *NEMO BS* when referring to the NEMO Basic Support protocol [6].

II. Scenario and System Architecture

The assumed scenario is general but nonetheless realistic: In fact it includes both safety and non-safety applications as well as multiple technologies, but it also defines a restricted set of features with respect to the automotive industry requirements, as expressed by the system architecture agreed within the Car-to-Car Communication Consortium [2].

The basis for effective, distributed communication technology in vehicles is its widespread deployment. The largest possible number of vehicles sold in the future should be equipped with communication capabilities. This must lead to the definition of a **basic system**, providing a set of fundamental functionalities, as opposed to various **extended systems**, which offer enhanced services and allow for differentiation among products from different car manufacturers and suppliers. Because safety is regarded as primary in vehicular communications, a basic system is required to provide a minimum set of protocols, algorithms, and applications that have been identified as most effective in preventing accidents. Applications that are not strictly safety-oriented could technically be included in the basic system. However, based on the fact that comfort and entertainment are usually not free of charge for users, it seems unrealistic for these services to be part of a basic system that primarily aims at being widespread. Therefore, in the remaining part of the section we mainly focus on the basic system, and note case by case how an extended system could offer specific enhancements.

Vehicular networks based on short-range communication involve several entities and different network domains, as depicted in Figure 1. Vehicles are equipped with devices termed *On-Board Units* (OBU), which implement the communication protocols and algorithms. Units of different cars can communicate with each other or with fixed stations installed along roads termed *Road Side Units* (RSU). OBUs and RSUs implement the same protocol functionalities and form a self-organizing network, here referred to as the *Ad-hoc Domain*. These units differ from each other with respect to the networks they are attached to: OBUs offer an interface to the set of driver and passenger devices present in a car, which are called *Application Units* (AUs). The mobile network, composed of AUs, defines a domain that is usually termed *In-Vehicle Domain*. RSUs can either be isolated or attached to a larger structured network. In the first case, 'isolated', their function is to distribute static information (e.g. dangerous curve, construction site ahead) or simply to extend the OBUs' communication range by acting as forwarding entities. In the latter, 'attached', RSUs distribute information towards or from a remote entity (e.g. control center). They can also connect the vehicular network to an infrastructure network, which is generally referred to as *Infrastructure Domain*.

As far as the **wireless technology** is concerned, a variant of Wireless LAN IEEE 802.11 is currently considered as best candidate for a basic safety-oriented system, especially in terms of propagation behavior and overall complexity. Frequency allocation around 5.9 GHz – in a protected frequency band dedicated to road safety – is either in progress (Europe [9]) or finished (US [10]). Due to *i*) limited available

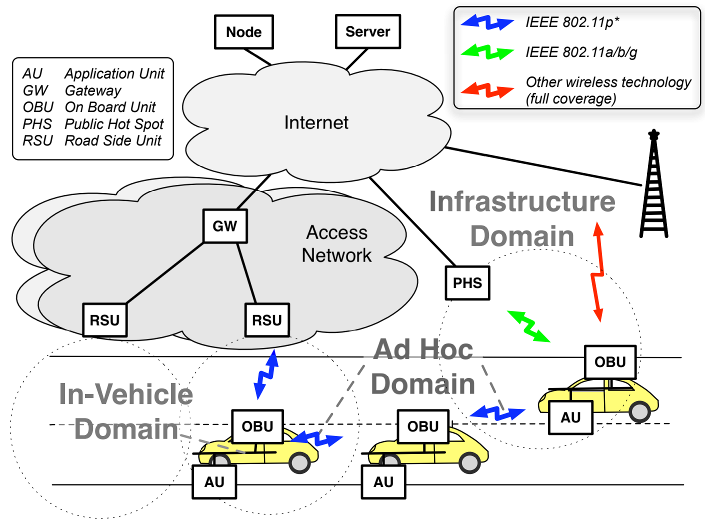


Fig. 1. System architecture, currently assumed by the Car-to-Car Communication Consortium (C2C-CC)

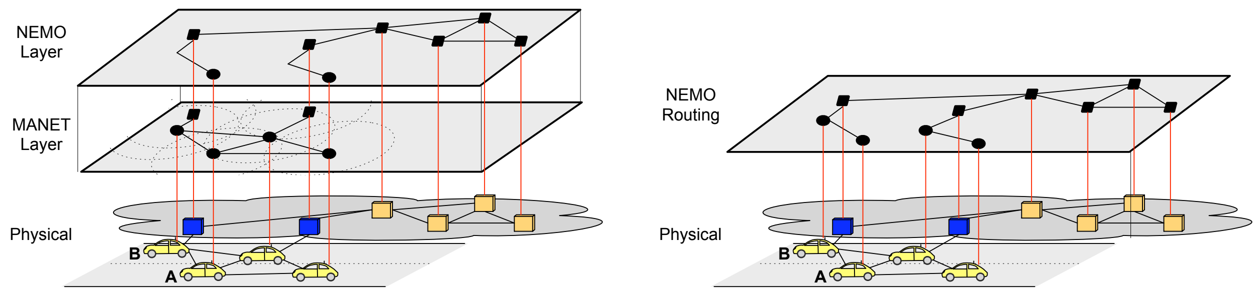
bandwidth compared with the large scale of VANETs, *ii*) high deployment complexity of multi-channel operation schemes and *iii*) lack of congestion control algorithms in IEEE 802.11 MAC suitable for scenarios with high vehicle density, the use of wireless resources has to be controlled in a distributed way, so that messages with high priority and hard real-time constraints can be delivered immediately. As a consequence, the allocated frequency bands will most likely be reserved exclusively for safety applications. Other types of data traffic, such as for comfort and infotainment, may rely either on different frequency bands[2] or on alternative wireless technologies. In particular, one or more variants of the IEEE 802.11a/b/g standard family could be installed in extended systems with minimum additional complexity.

III. Requirements for a Vehicular NEMO Solution

As pointed out, applications for vehicular communications can be roughly grouped into safety (e.g. hazard warning, work-zone warning) and non-safety (e.g. point-of-interest notification, Internet access). These application types put different and partially conflicting requirements on the system design.

Typically, non-safety applications establish communication sessions with their peer entities. Data is transmitted as packets from source to destination, using unicast or multicast. In contrast, safety applications data is commonly regarded as spatial and temporal *state information* that needs to be disseminated in geographical areas. This implies *in-network processing* that allows to aggregate, modify, and invalidate the information to be forwarded. The fundamentally different information dissemination strategy of safety applications results in unique protocol mechanisms for geographically-based data forwarding, congestion control, and reliable data transfer with strong cross-layer dependencies [11]. Clearly,

[2] At this point of time, it is not clear whether the European regulatory institutions will allocate only frequency bands for safety applications or also additional bands for non-safety.



(a) Manet-centric

(b) NEMO-centric

Fig. 2. Layer view

these mechanisms are not part of the standard TCP/IP protocol suite.

In order to reach a considerable number of equipped vehicles after market introduction, safety and non-safety applications must be integrated into a single system. In particular, a number of safety applications needs a minimum share of equipped vehicles for vehicle-to-vehicle communication. The support for non-safety applications is commonly regarded as a catalyst for successful market introduction of a safety communication system. In particular, use cases are being currently specified [12] and comprehend for example notification services (traffic, weather, news), peer-to-peer applications and generic file transfers from the Internet. Also, vehicular non-safety applications have not found wide deployment in the past – closed telematic platforms of vehicle vendors, high costs for the telematic hardware, and service fees are some of the reasons. It is expected that convenience (non-safety) applications will boom when integrated with a communication-based safety system [13], [14], [15].

We classify the requirements of non-safety applications into *economic*, *functional*, *performance*, and *deployability* requirements.

Economic Requirements. Costs represent an important factor for a vehicular communication system. Primarily, hard- and software of vehicular equipment must be inexpensive. Attractive non-safety applications, such as Internet-based applications, would point out a visible and immediate added value to customers. Two more aspects can promote a vehicular communication system: (i) An investment in fixed communication units at designated locations along the road – by public authorities or private road operators – helps to overcome the market introduction barrier. (ii) To provide a large customer basis, vehicular communication must provide business opportunities for Internet service provider to generate revenue.

Functional Requirements. A fundamental functionality of vehicular communication is the support of vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication. Clearly, V2I communication can only work when connectivity to a RSU exists, possibly via multiple wireless hops. Conversely, direct V2V communication must work without an RSU being available since intermittent RSU access is a basic assumption for the vehicular communication system. Moreover, if V2V and V2I are feasible simultaneously, policies should determine which communication mode to use. The following non-exhausting list points out additional functional requirements for non-safety applications:

- Vehicles carry unique identifiers for reachability via V2I and V2V communication,
- As a minimum, inexpensive solution, a vehicle equipped with only IEEE 802.11 technology can use V2I and V2V communication.
- Applications can utilize capabilities for geographic addressing specific to safety applications. This implies a mapping between IP addresses and geographical positions and areas.
- Data security for safety applications (authentication, integrity, non-repudiation) is a mandatory function since attacks by malicious nodes, as well as misconfiguration and malfunction can have disastrous effects [16]. Non-safety applications must not introduce new security leaks for safety applications or render the security measures useless.
- The privacy of drivers and passengers[3] is a strong concern; to protect privacy, the use of pre-assigned, quasi-random and changing identifiers – referred to as pseudonyms [17] – is considered for so-called revocable privacy in safety applications. Non-safety applications should not reveal additional personal information when being used, nor allow for linking changed pseudonyms by sending constant identifiers as cleartext.

Performance Requirements. The dominant factor that limits the performance of vehicular communication is the available bandwidth. Considering the potentially high relative velocity of vehicles, control traffic for network organization needs to be minimized. For networking, two aspects are important: *First*, for ad hoc routing in a vehicular environment a reactive scheme has significantly less signaling overhead than a pro-active scheme.[4] *Second*, IP mobility support for handover among road-side units/hot spots and for global reachability must cope with the nodes' high velocity.

Deployability Requirements. A NEMO solution must be asymmetrically deployable. This means that communication between nodes must be possible, where only one node is

[3]Obviously, communications that utilize geographical data for routing publicly disclose position, speed and driving direction.

[4]Pro-active schemes attempt to maintain an all times up-to-date routing information from each node to every other node in the network. Reactive routing protocols initiate a route discovery process on demand.

equipped with a NEMO solution and the other with a standard IPv6 protocol stack.

IV. Two Approaches for NEMO in MANETs

Due to the fundamentally different requirements and communication principles for safety applications, we limit the scope of the analysis to non-safety applications. Temporarily ignoring the specific aspects of VANETs as opposed to MANETs, we identify two approaches for integration of MANET routing protocols and NEMO: MANET-centric and NEMO-centric. For both approaches we first give a formal definition, then describe how the approach works in principle. Finally we list known instantiations of the approaches.

A. MANET-Centric Approach

***Definition** 1:* We define as MANET-centric a solution to apply NEMO in MANETs, in which multi-hop communication between a generic MANET node and infrastructure is achieved transparently by means of the MANET routing protocol, whereas NEMO runs on top of it.

In this approach, the multi-hop path between a MANET node and an attachment point which is out of its direct wireless communication range relies only on a distributed routing protocol which is executed by all nodes participating in the MANET. Automatic address configuration suitable for Movement Detection [7] as well as gateway selection are performed by the MANET routing protocol (more precisely, by dedicated extensions of the MANET routing protocol).

An important aspect of the MANET-centric approach is the fact that it allows for hiding the ad hoc nature of the MANET from the IP mobility management. Hence the MANET-centric approach clearly separates ad hoc and IP mobility functionalities. In fact, having a MANET routing protocol enhanced with the described features enables to run NEMO on top of it, without the need for specific changes to NEMO BS. In order to achieve this, the routing functionality of the network layer is split into two hierarchical layers. The lower layer represents the mobile ad hoc routing layer, whereas the upper layer is for mobility routing and relies on the routing to the attachment point (i.e. default route) provided by the MANET routing in the lower hierarchical layer (Figure 2(a)). As a consequence, from the perspective of the mobility protocol, the gateway selected by the routing protocol beneath it is directly reachable via a single-hop path. Thus, movement detection and handover signaling can be performed as in the usual case of a terminal directly connected to a base station. A conceptual protocol stack is shown in Figure 3.

We conclude this section citing some relevant examples of MANET-centric approaches. In [18] *Lorchat* et al. propose to integrate NEMO BS into an OLSR-based ad hoc network. This solution introduces information about the mobile prefixes in the pro-active signaling of OLSR, so that the nodes of the VANET will have individual routes for other nodes and mobile networks, whereas the default route is assigned to the tunnel MR-HA. In [8], *McCarthy* et al. propose an approach in which the MANET is seen as the NEMO Home Network for each of the mobile networks. This approach, designed for communication in a rescue team, does not apply to heterogeneous and large-scale networks like VANET, where a reference point like a rescue vehicle is not available. As a more general approach of Mobile IPv6 integration in MANET, we cite [19], in which *Wakikawa* et al. propose a mechanism for address auto-configuration and suggest how Mobile IPv6 could be used when a globally routable address is available.

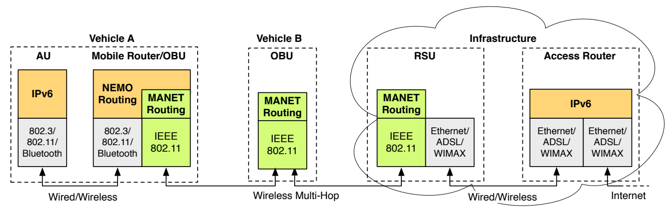


Fig. 3. Protocol stack for MANET-centric approach

B. NEMO-Centric Approach

***Definition** 2:* We define as NEMO-centric a solution to apply NEMO in MANETs, in which multi-hop communication between a generic MANET node and infrastructure is achieved passing through at least one NEMO Mobile Router running on a different node.

In this approach, the multi-hop path between a MANET node and an attachment point which is out of its direct radio range relies on one or more NEMO instances (Mobile Router) running on other nodes. Typically, in this approach one or more NEMO Mobile Router offer the connectivity to other nodes through themselves, becoming in this way gateways. A routing protocol for MANET can then be used to optimize routing between cars that rely on the same NEMO Mobile Router. In other words, the role of NEMO in this approach is to provide and maintain infrastructure connectivity, whereas the MANET protocol deals with routing issues internally to a mobile network.

The main issue that is targeted in this kind of approach is the fact that NEMO (not only NEMO BS but the notion of network mobility) is not designed to deal with unstructured topologies, but rather with **hierarchical topologies**. Its first deployment scenario, indeed, is a mobile network with direct (one hop) infrastructure connectivity, in which subnetworks can be formed inside. MANETs, on the other hand, do not naturally offer a hierarchy, therefore in the NEMO-centric approach a logical topology needs to be build by means of pro-active signaling among the Mobile Routers.

A particular approach of this type, on which recent research has been focusing, is the use of *nested* NEMO. According to the definition in [20], a mobile network is said to be *nested* when a mobile network (sub-NEMO) is attached to a larger mobile network (parent-NEMO). The aggregated hierarchy of mobile networks becomes a single nested mobile network. A precondition for a nested NEMO is that the Mobile Router of the sub-NEMO can attach itself, directly or indirectly, to the *ingress* interface of the Mobile Router of the parent-NEMO. Nevertheless, in the VANET basic system described in Section II, an OBU is equipped with only one (egress) interface to the ad hoc domain and one (ingress) interface to the in-vehicle domain. Assuming the technology of the in-vehicle network to be wired or very short range wireless (e.g. Bluetooth), the application of nested mobile networks to the VANETs considered in this scenario appears to be extremely complex[5], resulting in a considerable reduction of its potential benefits.

In Figure 2(b) the principle of the NEMO-centric approach is depicted, in which MANET routing and NEMO tunneled routing are executed by a single, merged protocol. Compared to the MANET-centric approach the hierarchy collapses into a single hierarchical layer. A conceptual protocol stack is shown in Figure 4.

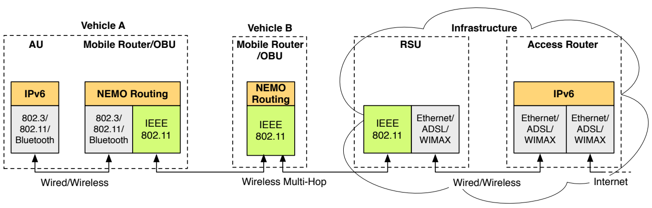


Fig. 4. Protocol stack for NEMO-centric approach

Various solutions that have been proposed for deployment of the NEMO protocol in MANETs follow the NEMO-centric approach. In fact, according to Definition 2, all solutions that refer not only to nested, but also to structured networks relying on a NEMO Mobile Router, belong to this category. For example, in [21] *Wakikawa* et al. propose to use a Mobile Gateway that runs NEMO and is permanently connected to the Internet by means of a wireless communication interface with wide spatial coverage. In [22], *Thubert* et al. propose a protocol that allows for building and managing trees in a nested NEMO topology. In [23] *Clausen* et al. propose to use OLSR to provide route optimization in nested NEMOs.

V. Analysis

After having described two main approaches for usage of NEMO in a MANET, this section goes back to the VANET scenario considered in Section II and analyzes the approaches adopting as criteria the requirements introduced in Section III.

A. Economic Criteria

Permanent Internet connectivity. Excluding some possible applications of [22], NEMO-centric schemes proposed so far assume that at least one MANET node has permanent connectivity to the Internet (usually referred to as *grounded Mobile Router*). Applied to VANETs, this principle on one hand enables many cars to enjoy Mobile IP features while only one car needs to have a subscription and execute the signaling. On the other hand, this relies on the strong precondition that in a cluster of vehicles always at least one *grounded Mobile Router* exists. In order this condition to be fulfilled, the majority of the vehicles needs to have permanent connectivity. This in turn is in contrast with the need for a widely spread, inexpensive technology.

B. Functional Criteria

V2I and V2V support. V2I is achieved in both approaches with comparable complexity, but with the already mentioned difference that NEMO is optional in the MANET-centric and mandatory for most vehicles in the NEMO-centric. Indeed MANET-centric approaches, relying on non-hierarchical logical topologies, can better offer V2I access also to cars not provided with NEMO. Regarding direct V2V mode (i.e. infrastructure not available) we argue that in the MANET-centric approach this functionality can be achieved with slightly less complexity and signaling cost, again due to the fact that all MANET nodes have equal routing tasks.

Reachability at unique identifiers. Even keeping in mind that a Mobile Network Prefix (MNP) should not be considered permanently assigned to a mobile network, it is possible to envision that a vehicle's network is identified by a MNP, both when connected to the Internet (via the Home Agent) and not (exposing the MNP in the ad hoc network) for an appropriate time interval. Again, the MANET-centric approach allows for an easier MNP resolution and switching between modes, because every vehicle manages directly its own MNP without delegating a different vehicle for that.

Applicability to the basic system. Another listed requirement is that vehicle equipped with only an IEEE 802.11 interface can use V2I and V2V communications. Most of the NEMO-centric existing proposals, as mentioned, rely on grounded Mobile Routers to provide V2I communication. Though the NEMO-centric paradigm is not limited to a multiple wireless interface system, its peculiar advantages (e.g. aggregation) disappear when applied to a single interface system. In fact, in the scenario of equally equipped, single-interface vehicles, the signaling overhead for maintaining a hierarchical topology overkills the signaling reduction for handover procedures. Therefore we argue that MANET-centric approaches better fulfill this requirement.

Geographical addressing. The support of geographically addressed data packets requires particular routing functionalities in both infrastructure and ad hoc domain. In the first, packets routing follows the topological structure of IP prefixes and can not be adapted to follow geographical routing. A possible approach is to maintain repositories for mapping geographical areas into IP addresses of RSUs.[6] In the ad hoc domain, the routing from the RSU to the targeted area requires a MANET routing protocol that is aware of geographical positions. We argue that this functionality can be achieved only by means of a MANET-centric approach, due to the fact that NEMO-centric approaches establish a logical hierarchical topology that can not continuously reflect the geographic topology of vehicles.

[5]In particular we refer to the usage of one IEEE 802.11 physical interface as egress and ingress at the same time through interface virtualization, which makes it extremely complex to enforce effective cross-layer algorithms, e.g. for congestion control.

[6]More precisely, these repositories could provide, starting from a specified geographical area, the addresses of the access routers where RSUs are attached to.

C. Performance Criteria

Minimal routing state. As can be concluded from the description of Section IV-B, the NEMO-centric approach extends the network mobility support by ad hoc routing. Because of their need for a logical hierarchical topology, the scheme utilize pro-active signaling, e.g. to build and maintain the tree structure as in [22] or to elect the mobile gateway in [21]. The use of pro-active signaling and, in particular, the consequent creation of *routing states* and their maintenance in routing tables is controversial in VANETs. Research activities focused on this scenario, e.g. [24], have shown that the cost for maintenance of distributed topology states is too high with respect to the available wireless bandwidth. Thus, for VANETs, hybrid pro-active/reactive and mainly stateless routing protocols, preferable based on geographic positions, seem to be more efficient, where nodes are pro-actively aware only of neighbors that are inside the radio range and, optionally, of attachment points to the infrastructure.

VI. Summary and Conclusions

In this document we analyzed the applicability of network mobility concepts (NEMO) to vehicular ad hoc networks (VANETs).

According to the objectives of VANETs to support safety and non-safety applications and their specific requirements, we first stated that the traditional IP-based protocol suite is principally not applicable for safety applications due to the fundamentally different communication paradigm. For non-safety, VANETs have a number of similarities with common mobile ad hoc networks but requirements (such as high mobility of nodes and frequent changes in the network topology, support of geographical addressing) will most likely lead to a specific VANET routing protocol, that is suitable to serve safety and non-safety applications.

For the integration of VANETs with NEMO we first considered possible approaches to combine MANET routing protocol with NEMO. We classified them in two main categories according to the roles of protocols in the network architecture, i.e. MANET-centric and NEMO-centric approach. Then, we compared the two approaches with respect to VANET-specific requirements. We conclude that for a VANEMO solution, a 'MANET-centric' approach seems to be more appropriate because it allows a cleaner, modular integration at lower complexity with respect to economic, functional and performance criteria. In detail, we conclude that MANET-centric allows for:

- a more cost-efficient solution,
- easier direct V2V communication with intermittent infrastructure access,
- less complex support of geographic addressing,
- better routing performances, because of easier integration with reactive, VANET-specific ad hoc routing protocols.

While the above issues indicate an advantage of the MANET-centric approach over the NEMO-centric approach, we stress that currently no ready solution for NEMO in VANETs exists and important aspects like routing consistency, privacy, and security need considerable research efforts. We regard this document rather as a contribution to ongoing discussion and hope that it stimulates discussions about the automotive-specific requirements.

VII. Acknowledgments

The authors would like to thank in particular Thierry Ernst, Carlos J. Bernardos and Thomas Clausen. Andreas Festag acknowledges the support of the German Ministry of Education and Research (BMB+F) for the project 'NoW – Network on Wheels' under contract number 01AK064F.

References

[1] "Vehicle Infrastructure Integration (VII)," http://www.its.dot.gov/vii/.

[2] "Car 2 Car Communication Consortium," http://www.car2car.org.

[3] "Internet ITS Consortium," http://www.internetits.org.

[4] "DSRC Working Group," http://grouper.ieee.org/groups/scc32/dsrc/.

[5] ISO TC 204 ETSI ERM TG37, "The CALM Handbook," Sep. 2004.

[6] V. Devarapalli, R. Wakikawa, A. Petrescu, and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol," RFC 3963, Jan. 2005.

[7] D. Johnson, C. Perkins, and J. Arkko, "Mobility Support in IPv6," RFC 3775, June 2004.

[8] B. McCarthy, C. Edwards, and M. Dunmore, "The Integration of Ad-hoc (MANET) and Mobile Networking (NEMO): Principles to Support Rescue Team Communication," in *Proc. ICMU*, London, U.K., Oct. 2006.

[9] S. Hess, "Frequency spectrum for ITS Status Report of July 2006," COMeSafety, July 2006.

[10] FCC Rules and Regulations, "Regulations Governing the Licensing and Use of Frequencies in the 5.850 - 5.925 MHz Band for Dedicated Short Range Communications Service," Aug. 2004.

[11] M. Torrent-Moreno, A. Festag, and H. Hartenstein, "System Design for Information Dissemination in VANETs," in *Proc. WIT*, Hamburg, Germany, March 2006, pp. 27–33.

[12] R. Baldessari, A. Festag, and M. Lenardi, "C2C-C Consortium Requirements for Usage of NEMO in VANETs," IETF, Internet Draft Version 00, Feb. 2007.

[13] ABI Research, "Dedicated Short Range Communications (DSRC) – The Emerging Wi-Fi and RFID Market for Advanced Automotive Identification, Commerce and Communications," Research Report, May 2005.

[14] K. Matheus, R. Morich, and A. Lübke, "Economic Background of Car-to-Car Communications," in *Proc. IMA*, Braunschweig, Germany, Oct. 2004.

[15] K. Matheus, R. Morich, I. Paulus, C. Menig, A. Lübke, B. Rech, and W. Specks, "Car-to-Car Communication - Market Introduction and Success Factors," in *Proc. 5th European ITS Congress and Exhibition*, Hannover, Germany, June 2005.

[16] A. Aijaz, B. Bochow, F. Dötzer, A. Festag, M. Gerlach, T. Leinmüller, and R. Kroh, "Attacks on Inter Vehicle Communication Systems - an Analysis," in *Proc. WIT*, Hamburg, Germany, March 2006, pp. 189–194.

[17] E. Fonseca, A. Festag, R. Baldessari, and R. Aguiar, "Support of Anonymity in VANETs – Putting Pseudonymity into Practice," in *Proc. WCNC*, Hong Kong, March 2007.

[18] J. Lorchat and K. Uehara, "Optimized Inter-Vehicle Communications Using NEMO and MANET," in *Proc. V2VCOM*, San Jose, CA, USA, July 2006.

[19] R. Wakikawa, J. Malinen, E. Perkins, A. Nilsson, and A. Tuominen, "Global Connectivity for IPv6 Mobile Ad Hoc Networks," IETF, Internet Draft (Expired) Version 05, Mar. 2006.

[20] T. Ernst and H.-Y. Lach, "Network Mobility Support Terminology," IETF, Internet Draft Version 06, Nov. 2006.

[21] R. Wakikawa, K. Okada, R. Koodli, and A. Nilsson, "Design of Vehicle Network: Mobile Gateway for MANET and NEMO Converged Communication," in *Proc. VANET*, Cologne, Germany, Sep. 2005.

[22] P. Thubert, C. Bontoux, and N. Montavont, "Nested Nemo Tree Discovery," IETF, Internet Draft Version 04, Nov. 2006.

[23] T. Clausen, E. Baccelli, and R. Wakikawa, "Route Optimization in Nested Mobile Networks (NEMO) using OLSR," in *IASTED International Conference on Networks and Communication Systems (NCS 2005)*, Krabi, Thailand, April 2005.

[24] A. Festag, H. Füßler, H. Hartenstein, A. Sarma, and R. Schmitz, "FleetNet: Bringing Car-to-Car Communication into the Real World," in *Proc. of 10th ITS World Congress and Exhibition*, Nagoyoa, Japan, Nov. 2004.