

Advances in MANEMO: Definition of the Problem Domain and the Design of a NEMO-Centric Approach

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Abstract

The integration of MANET and NEMO technologies to produce what are commonly termed MANEMO solutions is a burgeoning concept that has the possibility to provide IP connectivity across many diverse problem areas. However, even in research terms MANEMO is in a very early stage of development and consequently no standardised understanding of what MANEMO specifically refers to has yet been decided upon. In this paper we introduce the MANEMO concept as a whole and identify what we believe to be the two main solution areas contained in the MANEMO problem domain, namely NEMO-Centric MANEMO (NCM) and MANET-Centric MANEMO (MCM). In addition to defining these two instances of MANEMO we also highlight the design decisions and implementation considerations that are encountered when developing an NCM protocol through the introduction of our NCM protocol implementation that we are currently producing at Lancaster University.

1 MANEMO Concept

The MANEMO (MANET-NEMO) concept has developed from the requirement to optimise packet delivery paths in scenarios which produce nested NEMO structures. This area has begun to gather increasing levels of interest throughout the mobility research community but even the term MANEMO itself still remains relatively undefined. In this paper we propagate our opinion that the convergence of the two technologies MANET and NEMO is a mutually beneficial process and can thus benefit both NEMO based and MANET based scenarios; the authors of this paper identify these separate instances as NEMO-Centric MANEMO (NCM) and MANET-Centric MANEMO (MCM). Throughout the remainder of the pa-

per we refer to a collection of NEMO networks which route packets locally using a MANET protocol as a MANEMO.

1.1 NEMO-Centric MANEMO (NCM)

NEMO-centric MANEMO describes the scenario where numerous, disparate NEMOs converge to form a Nested NEMO network and then a MANET protocol is utilised to optimise delivery within the nested structure. In this scenario, if the NEMOs were to use NEMO Basic Support protocol (NEMO BS) [1] to maintain connectivity, packets sent between 2 NEMOs within the nested structure would traverse a highly inefficient route via each of the HAs of the respective NEMOs that are in the path the packet traverses. This routing sub-optimality is often referred to as Pinball Routing (or Multi-Angular Routing) and is illustrated in Figure 1. The illustration shows how for a packet to be sent from Node A on NEMO 1 to Node B on NEMO 2, the packet must first be tunneled through the destination NEMO onwards to its Home Agent (HA1) at which point it is decapsulated and sent back to NEMO 2 via HA2 (back along the same path it travelled out to HA1).

This process is obviously highly inefficient and so accordingly, a number of solutions to optimising this situation have been proposed by members of the IETF NEMO Working Group [2]. The concept of combining MANET and NEMO was suggested as one possible solution, it was born from the observation that when the NEMO Mobile Networks converge in the same location to form a nested NEMO structure, this structure itself (locally) is actually a mobile ad-hoc network of NEMO mobile networks. Therefore, local delivery can be best performed between NEMOs in the Nested NEMO structure using a MANET routing protocol (extended to support network prefixes). Although no specific draft proposal was ever submitted to the NEMO WG, the possibility of combining MANET and NEMO in

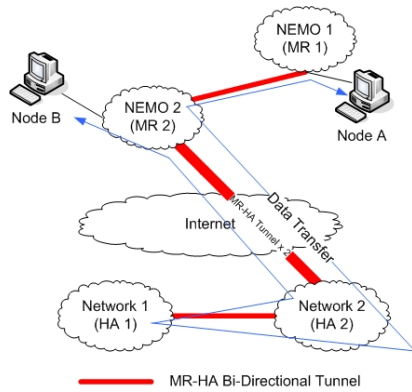


Figure 1. Example of Nested NEMO Route Sub-Optimality

this manner was mentioned in the NEMO WG RO Space Analysis draft [3] and a slightly more detailed example was published at the IASTED Networks and Communication Systems conference [4].

We define a NEMO-Centric MANEMO scenario as being one in which the NEMOs in their typical state follow the NEMO BS model, i.e they are distinct mobile networks that typically roam across access networks in a non-nested structure. However, in the event of a roaming NEMO attaching to another NEMO (or possibly another nested NEMO), packet delivery within the nested structure is optimised through the use of a MANET protocol. The optimisations this technique affords come in many conceivable forms. For example, in the case of local delivery (where packets originate from one NEMO within the nested structure and are destined for another NEMO within the same nested structure) it allows the packets to be routed directly to the appropriate NEMO without visiting any HAs or leaving the nested structure. Another advantage is that packet delivery to a NEMO within a Nested NEMO from a source that is outside the nested structure can also be optimised with this technique. Instead of blindly forwarding packets to every HA of every NEMO that must be traversed within the nested NEMO, an NCM protocol can instead forward packets directly to a Mobile Router (MR) that has global connectivity (what we call a Grounded MR) and allow the MANET routing protocol to handle delivery from that point onwards. This technique also ensures that any mobility of NEMOs within the MANEMO need not be reported back to their respective HAs.

An example scenario of where this solution could be applied is vehicle to vehicle intercommunication. By using an NCM solution, a vehicle could ensure that devices within its Vehicle Area Network (VAN) were permanently reachable via its HA (located in a depot or home) whilst also

supporting efficient inter-vehicle communication with other vehicles in its local vicinity. This would allow the vehicle to share important information with vehicles in its immediate surroundings (such as road surface conditions, or warn vehicles behind of an upcoming crash). The vehicle could also benefit from connection sharing, whereby if the vehicle has no access to an infrastructure connection, it can attempt to route packets destined for the Internet via other vehicles.

1.2 MANET-Centric MANEMO (MCM)

MANET-Centric MANEMO (MCM) describes the scenario where a collection of NEMOs are by default part of an Ad-hoc structure (a MANEMO) and for them to move away from this structure is the non default case. In this situation it is the MANET protocol that will perform the bulk of the routing and the NEMO protocol that is engaged in the specialised case (vice-versa to the NEMO-Centric scenario). This specialised case occurs when a NEMO has disconnected from the MANEMO it originated in but is able to utilise a backup infrastructure connection (such as a satellite link or UMTS connectivity). In this situation the disconnected NEMO will utilise an MR-HA tunnel in order to send and receive packets to and from the MANEMO. This technique allows the remote NEMOs location to be kept transparent, so they appear to still be directly connected to the same MANEMO. This communication model, illustrated in Figure 2 is applicable to many mobility scenarios, including disaster rescue, military and mountain rescue team communication [5].

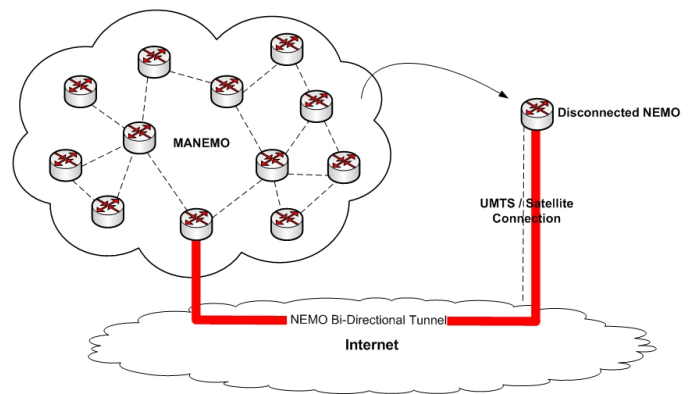


Figure 2. MANET-Centric MANEMO, General Model

The main distinction between a MANET-Centric and a NEMO-Centric MANEMO approach arises when we consider the role and location of HAs and the Home Networks in general. With NEMO-Centric MANEMO, a HAs role and its subsequent location follows the same model as with NEMO BS, however with MANET-Centric MANEMO it is

intended that the the MANEMO itself is considered to be the Home Network of each of the NEMOs that belong to it. This distinction represents a big change in the overall conceptual model, and generates two distinct scenarios, which affect the possible solutions:

1) **Anchored MCM:** Anchored MCM represents the simplistic model whereby the MANEMO can be assumed to have a permanent, reliable, fixed point of connection to the Internet where an MCN enabled HA can reside (such as a Head Quarters or a static vehicle with a satellite uplink) and therefore this anchor point can be used as a permanently reachable gateway back into the MANEMO.

2) **Non-Anchored MCM:** The Non-Anchored MCM model represents the more complex scenario whereby the MANEMO itself has multiple, changing points of attachment to the Internet. In this situation we have no fixed anchor point which we can use to enable NEMOs to tunnel back into the MANEMO. Therefore in order to produce a successful solution to this problem, any NEMO must be able to learn of the current MANEMO anchor points automatically and any anchor point must be able to act as a temporary HA to the rejoining NEMO.

2 NCM Protocol Description

It is the intention of the Network Mobility research team at Lancaster University to develop both an NCM and an MCM protocol implementation. In this section we outline the design decisions and operational alterations that we made to the NEMO BS protocol and the Optimized Link State Routing protocol (OLSR) [6] in order to develop our NCM implementation. As outlined in section 1.1 the basic principle of an NCM protocol is to forward any packet arriving at an MR's HA onto one of the MRs in the MANEMO that has a direct infrastructure connection (Grounded MR); then from this grounded MR, the packet will be routed within the MANEMO using a MANET routing protocol. The process is then reversed to provide optimised packet delivery from an MR within a MANEMO, out to a node on the Internet or to another MR in the MANEMO.

2.1 Mobile Router (MR) Operation

An NCM enabled MR will operate in the same manner as a normal NEMO enabled MR whenever: A) It is roaming using a global infrastructure connection and B) it has no other NCM enabled MRs attached to it. If either of these conditions are broken then the MR enters an NCM operational state, depending on which condition changes the MR will perform in different ways. If the MR maintains an infrastructure connection but another NCM enabled MR attaches to it then it will assume the role of a Grounded MR. In this operational state the MR will communicate as

it would with NEMO BS with regards to maintaining a binding with its own HA, however the MR will now begin to intercept packets not addressed to its network prefix and subsequently forward them over its MANET interface against the MANET routing table it maintains. In contrast, if the MR is located within the MANEMO with no infrastructure connection it will only send and receive packets over its MANET interface. The MR will still perform a Binding Update (BU) process with its HA, but it will not setup any tunnel. Instead it will send its BU messages to the HA of the nearest Grounded MR (which the MR will have discovered through the Host and Network Association (HNA) messages that the Grounded MR propagates in the MANEMO) and then onward to its HA. The resulting binding process is then performed by the MRs HA (detailed in Section 2.2). Throughout its operation, the MR signals whether it is currently a Grounded MR or located within the MANEMO by setting a flag bit (the NCM flag) in the header of the BU message. If the MR signals that it is Grounded, its CoA will have been obtained from an infrastructure network. However if the MR signals that it is located within the MANEMO, it will set its CoA to be the address of the Grounded MR, to help the Grounded MRs HA identify which tunnel it must forward packets destined for the Non-Grounded MR over.

2.2 Home Agent (HA) Operation

The functionality of the HA again alters dependent on whether the MR is Grounded or located deeper within the MANEMO. If the MR that is binded to the HA is Grounded and packets received by the HA are destined for nodes attached to the Grounded MR, the HA will operate in the same way a NEMO enabled HA would. Alterations to this model occur when we consider MRs which are located within a MANEMO. As an MR attaches to the MANEMO it attempts to send a BU message back to its HA, in doing so the BU message is first routed out of the MANEMO towards the Grounded MR by the MANET protocol. The Grounded MR then forwards the BU message onto its HA, when the HA receives the BU message it checks the BU header message for the NCM flag bit. If the NCM flag bit is set and the CoA provided corresponds to the address of one of the MRs registered with that HA, the HA records which MR-HA tunnel the BU message was received from. It then proceeds to repopulate the CoA field with its own global IPv6 address, keeps the NCM flag bit in tact and forwards the BU on to the Non-Grounded MR's HA. This flag now indicates to the HA of the Non-Grounded MR that the binding request is now being made by the HA of a Grounded MR. The Non-Grounded MR's HA, upon receiving a valid BU message with the NCM flag set, will not recognise the CoA provided as the address of one of its registered MRs and thus will at-

tempt to setup a bi-directional tunnel directly with the HA of the Grounded MR.

Data transfer in this situation is illustrated in Figure 3. In the illustration packets generated by the CN that are destined for nodes attached to MR2 are affected by two levels of indirection because they visit HA2 and HA1 respectively before reaching the MANEMO and are only ever subjected to one layer of encapsulation (although decapsulation and recapsulation does occur once at HA1). In a pure NCM situation this is the extent of the indirection and encapsulation that is experienced by a packet no matter how many MRs are contained within the MANEMO, unlike with NEMO BS where the levels of indirection and encapsulation increase considerably as the Nested NEMO structure increases in size. Furthermore, a MIPv6 style Route Optimisation technique could conceivably be employed to support direct communication between HA2 and the Grounded MR (MR1), this form of optimisation would result in packets being subjected to the optimal overhead of only one level of indirection and one instance of encapsulation.

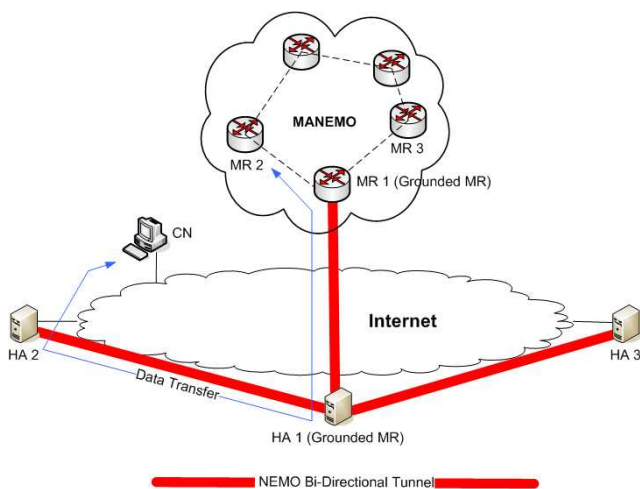


Figure 3. Overview of the NCM Model

2.3 MANET Alterations

In addition to the alterations made to the HA based approach of NEMO, the MANET protocol (OLSR) chosen to perform routing within the MANEMO requires minor alterations to support NCM as well. For example, the OLSR protocol was originally designed to be utilised by host devices and therefore supports forwarding based on specific addresses, however in our implementation the OLSR protocol must be optimised to support routing via network prefixes. The optimised OLSR protocol is used to forward packets up to the appropriate MR, beyond which the MR

itself handles the forwarding of packets to specific devices based on the IPv6 destination address.

Another alteration has also been made to the way the MANET protocol advertises Internet reachability within the MANEMO. Under normal operation, OLSR would advertise the network address and prefix of the Access Router that the Grounded MR has a connection with (i.e. the Grounded MRs CoA). With our MANEMO implementation however, the Host and Network Association (HNA) messages used by OLSR to propagate this information throughout the MANEMO are modified to advertise routes to the Internet via the MR-HA bi-directional tunnel of the Grounded MR.

3 Future Work

In addition to the NCM protocol described in this paper, our intentions are to also develop an MCM protocol solution that will support all aspects of the MCM problem area. Our MCM protocol development will be based around our continuing work to provide a complete IP communication solution for mountain rescue teams.

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