Gateway Selection Architecture Using Multiple Metrics for Vehicular Networking

Jirawat Thaenthong and Steven Gordon
Sirindhorn International Institute of Technology, Thammasat University,
131 Moo 5, Tiwanont Road, Bangkadi Muang Pathumthani 12000, Thailand

Abstract: Multi-hop wireless networks formed between vehicles on a highway can provide Internet access to
devices onboard vehicles if subsets of vehicles also share 3G/4G wireless connectivity to roadside base
stations. In such a scenario mobile routers onboard vehicles should select the optimal gateway (base station)
for Internet connectivity. This paper proposed an architecture that allows mobile routers to discover nearby
gateways and select the optimal gateways based on various performance metrics. The architecture extends the
Neighbour Discovery Protocol so that mobile routers can efficiently learn the identities and capabilities of
gateways across multiple hops. A new gateway selection algorithm is presented; the algorithm can use multiple
metrics, including gateway throughput, network load, path stability and financial cost, to determine the optimal
gateway. Simulation results show that increase in application throughput of 10-20% can be achieved at the
expense of small increase in signaling overhead.

Key words: Vehicular networks, ad hoc networks, mobile IP, MANEMO, path reliability, gateway selection

INTRODUCTION

Vehicle communication networks are formed by connecting devices inside public and private vehicles
with each other (vehicle-to-vehicle communications) and with fixed communication infrastructure (vehicle-to-infrastructure communications). Providing Internet access to devices (and users) in vehicles enables
various applications in safety and emergency warning, traffic management and entertainment. With diverse
communication capabilities of devices/vehicles, multi-hop wireless communications will be needed for some vehicles
to connect with the road-side infrastructure. That is, a mobile ad hoc network (MANET) is formed between
vehicles using IEEE 802.11p wireless links, while selected vehicles also offer 3G/4G links to nearby mobile network
base stations (as illustrated in Fig. 1). The vehicles contain fixed and mobile nodes, with a mobile router
managing mobility of all nodes in the vehicle on their behalf, thereby offering Network Mobility (NEMO). A
problem therefore is which base station, or gateway, should a vehicle use to access the Internet.

In infrastructure-based wireless networks, a mobile node has a single wireless link to a base station or
gateway. Therefore, link-level measures can be used to detect available gateways, measure link quality and obtain
status information from the gateways to support gateway selection. However when a mobile node is part of a
multiple-hop vehicular network it may not have a direct link to gateways. Therefore, new network-level protocols
are needed for a mobile node to discover gateways. Also the best gateway will not depend on just a single link, but
the other nodes in the network. Hence appropriate metrics for selecting the gateway are needed (Dhar et al., 2011)
and values of these metrics must be obtained such that the network overhead is minimized. Another challenge
is minimizing the overhead when performing a handover between gateways using protocols such as
Mobile IP and NEMO (Alrashdan et al., 2011, Dinakaran and Balasubramanie, 2012). This paper addresses these
problems by presenting a gateway selection architecture that:

- Extends Mobile IPv6/NEMO Route Advertisements to allow mobile nodes to learn about gateways and
  their capabilities
- Specifies key metrics for selecting an optimal gateway
- Presents an algorithm for selecting the gateway with the aim of improving application performance will
  minimizing communication overhead

The solution is tailored for highways, where gateways from multiple service providers are nearby the
roads and vehicles across multiple lanes form a network
amongst themselves, with a subset of vehicles also connecting to gateways.

Connecting a multi-hop wireless network (including MANET) to the Internet presents several challenges (Ding, 2008), one of those being how mobile nodes select the Internet gateway.

Several researchers have proposed gateway selection algorithms for specific MANET routing protocols. Bin and Bin (2009) modify AODV to use hop count and number of mobile nodes registered at gateways as selection metrics. The algorithm can balance load across multiple gateways. Sun et al. (2009) modify OLSR and use the same metrics as Bin and Bin (2009), as well as energy, queue delay and mobility history. These provide useful ideas but are limited to a specific routing protocol and the given metrics. Other metrics considered by researchers include route availability and latency by Bouk and Sasase (2009), path quality by Ma and Liu (2009) and gateway load by Sheng et al. (2008). However these algorithms are only tested in small networks of two or less hops. Other hybrid gateway selection algorithms using multiple metrics are proposed by Hoffmann and Medina (2009), Le-Trung et al. (2008) and Park et al. (2007). However the solutions consider only simple traffic patterns and limited mobility. Setiawan et al. (2009) showed how to normalize metrics within a range of [0,1] and combining them with a weighting function.

Focusing on vehicular networks where the gateway to select is fixed, Benslimane et al. (2011a) makes use of the Route Expiration Time (RET) Su et al. (2000) to select a gateway that has a reliable path to the mobile node. Benslimane et al. (2011b) use a cluster-based routing protocol and multiple metrics, including RET, signal strength and mobility patterns to select gateways. These are promising solutions, but can be improved by considering other metrics, especially application throughput. Another approach by Sheng et al. (2008) introduces a mobility management server to assist in gateway selection. Although producing good results, this is limited to networks which are controlled only by a single organization (i.e., does not support roaming between operators).

The aim of this research was to develop generic gateway selection architecture for vehicular networking that is independent of the underlying routing protocol and can support a variety of metrics. Focusing on a highway scenario, a solution is designed that is compatible with standard IP-based protocols, thereby allowing for deployments in a wide range of scenarios.
PROPOSED GATEWAY SELECTION ARCHITECTURE

After setting out the assumed scenario in this research, this section presents a generic protocol for MNs to collect metrics, list a set of metrics that should commonly be supported and the algorithm for selecting gateways.

Scenario and assumptions: The scenario under consideration is a multi-lane straight highway with V vehicles travelling in one direction with speed s. There are roadside gateways evenly spaced, separated by d kilometers. Each vehicle has its own IP subnet. There is one Mobile Router (MR) in the vehicle which, using NEMO (Devarapalli et al., 2005), manages the mobility of the subnet that may consist of Local Fixed Nodes (LFNs), Local Mobile Nodes (LMNs) and Visiting Mobile Nodes (VMNs). Each MR (as well as VMNs) have a Home Agent (HA) in the Internet. Communications within the vehicle can be with any wired/wireless technology. Communications between vehicles is with IEEE 802.11p. Selected vehicles also have a second wireless interface (e.g., 3G) for communications to roadside gateways. For position, all vehicles and gateways have built-in GPS device.

The routing protocol used within the vehicular network is not specified, but it is assumed the routing protocol can find least-cost paths across the network, e.g., from any mobile node to any destination, including a gateway. Most VANET routing protocols, e.g., Huo et al. (2011), or enhanced MANET routing protocols, e.g. Sharma et al. (2006), Tingrui et al. (2011), would be suitable.

IPv6 is used as the network layer. AUTOCONF and IPv6 stateless address autoconfiguration are used for assigning IP addresses to MR/MN. Mobile IPv6 is used for handovers between gateways. That is, to inform a MN/MRs home agent of its new address binding Mobile IPv6 Binding Update procedure is used. To reduce the delay of this procedure, support for Fast Handovers, e.g. (Koodli, 2009) or (Kusin and Zakaria, 2011), is assumed.

Gateway selection metrics: There are many metrics that can be used to determine the optimal gateway for a mobile node (performance, financial, security etc.). The final selection will depend on the network operator and user requirements.

The metrics under consideration in this study are:

Hops to gateway: The number of wireless hops the mobile node is from the gateway. This is an approximate measure of path delay and throughput in a multi-hop wireless network. It can be easily measured and is relatively stable (compared to say the actual path delay). It is commonly used for path and gateway selection. Hops to gateway is used as a baseline metric for comparing the usefulness of other metrics and the gateway selection algorithm.

Gateway Throughput: The egress throughput remaining at the gateway. On the uplink (to the Internet) the gateway records current throughput (either at a packet/byte level or by number of sessions) and determines the remaining throughput available to new sessions.

Traffic Load: The amount of traffic in the multi-hop wireless network. Getting an accurate, up-to-date measure of load in a multi-hop wireless network can be difficult. The load is approximated by counting the number of sessions, N_{load}, assuming each session has a sending rate of u. The sessions initiated by nodes in the vehicle, v_i, contribute to the load. Also, each vehicle, v_i, has a set of one-hop neighbours, v_{i,one}. The number of sessions that those neighbors have ongoing contributes to the load at v_i. Finally, the sessions from other nodes directed to vehicle v_i contribute to the load at v_i. Therefore the traffic load at v_i, denoted as L_{v_i} is the sum of these three contributions:

$$L_{v_i} = (N_{load} u_i) + \sum_{j \in v_{i,one}} N_{load} u_j + \sum_{k \in \text{neighbours}} N_{load} u_k$$  (1)

Therefore the traffic load from MN to gateway g is:

$$L_g = \sum_{v_{g,one}} L_{v_i}$$  (2)

where v_{g,one} is the set of intermediate vehicle between MN and gateway g.

Route Expiration Time (RET): A measure of how much time a MN can use a path to a gateway, i.e., the reliability of the path. Proposed by Su et al. (2000) each gateway embeds position, velocity and estimated RET (initially 0) in RAs. As MRs receive the RA they calculate a Link Expiration Time, update the RET and forward the RA. The RA received by vehicle v_i should have an estimate of the reliability of the path to the original gateway. LET is calculated as:

$$\text{LET}_v = -\frac{-(ab + cd) + \sqrt{(a^2 + c^2)r^2 - (ad - be)^2}}{a^2 + c^2}$$  (3)

where:

$$u_v = v \cdot \cos(\theta) - v \cdot \cos(\theta)$$
Fig. 2: Header structure for Route Advertisement packet, including optional source link-layer address and prefix info headers

\[ b_i = x_i - x_j \]

\[ c_i = v_i \sin(\theta_i) - v_i \sin(\theta_j) \]

\[ d_i = x_i - y_i \]

RET is calculated as:

\[ \text{RET}_k = \min\{\text{LET}_k\} \quad (4) \]

**Path stability:** A measure combining path reliability and length. RET measures path reliability, however a new metric is developed that also includes the path length in hops. That is, a stable path should have high reliability and low number of hops. Based on Benslimane et al. (2011a), the stability function of a path \( k \) is defined as:

\[ S_k = 1 - e^{\frac{p}{k}} \quad (5) \]

where

\[ p = \frac{a}{c} \]

\[ \bar{a} = \left\{ \frac{v_i}{\min\{v_i\}} \right\} \cos(\theta) \]

\[ \bar{c} = \left\{ \frac{v_i}{\min\{v_i\}} \right\} \sin(\theta) \]

and \( k = 1, 2, \ldots \), is the number of routes to each gateway and \( p \) is a constant based on \( a \) and \( c \) as all vehicles move in the same direction.

**Information collection:** A mobile node must discover the available gateways and collect information to make an informed selection of the gateway to use. The Neighbor Discovery Protocol (NDP) is designed for such tasks in IP networks. In NDP a gateway periodically broadcasts a Route Advertisement (RA) to its 1-hop neighbors. A MR that receives a RA will forward to nodes within its mobile network, i.e., LMNs, VMNs and LFNs. In addition to RAs, a MR may initiate discovery by broadcasting a Route Solicitation, to which a gateway may respond with a RA. The default format of a RA packet, including the two optional headers, is shown in Fig. 2.

NDP is designed for RA delivery across only 1 hop. The first proposed extension of NDP is to allow for RAs to traverse multiple hops (similar to that by Wakisaka et al. (2006)). A hop-limit is used to ensure the RA is not sent continuously, as illustrated in Fig. 3.

The second proposed extension is to carry metric information in the RA. Figure 4 illustrates the extended RA header that can carry information for the metrics listed in the previous section. Similar extensions can be defined for other metrics as needed.

With the extended NDP a gateway broadcasts a RA and receiving MRs forward the RA to its mobile network nodes, as well as to other MRs. With this approach nodes in the network can learn information about the gateway and network, even if further than 1 hop away.

**Gateway selection algorithm:** A VMN or LMN on-board a vehicle must choose the appropriate gateway to the Internet. The proposed method requires gateways to periodically broadcast metric information using the extended RA’s (Fig. 4). As MN’s receive RAs they use the information to calculate a gateway index for each gateway and then select the gateway with the highest index. The gateway selection algorithm is shown in Fig. 5.

A MN receives RAs, containing information about the network, at varying times. Each MN is configured with a decision interval, \( p \), the time between updating the gateway index. When it is time to update the gateway
Fig. 3(a-b): Comparison of hop limits in NDP, (a) Standard NDP allows only 1-hop, (b) The proposed extension supports multiple hops. GW: Gateway, MR: Mobile Router, MGW: Mobile Gateway, MN: Mobile Node, RA: Route Advertisement.

<table>
<thead>
<tr>
<th>Code</th>
<th>Length</th>
<th>Hop to GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>(000)</td>
<td>(13 bits)</td>
<td>(1 Byte)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Length</th>
<th>GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(001)</td>
<td>(13 bits)</td>
<td>(8 Bytes)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Length</th>
<th>GW throughout remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>(010)</td>
<td>(13 bits)</td>
<td>(2 Bytes)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Length</th>
<th>Traffic load of MR 1</th>
<th>Traffic load of MR N</th>
</tr>
</thead>
<tbody>
<tr>
<td>(011)</td>
<td>(13 bits)</td>
<td>(2 Bytes)</td>
<td>(2 Bytes)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Length</th>
<th>Financial cost of GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>(100)</td>
<td>(13 bits)</td>
<td>(2 Bytes)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Length</th>
<th>Sender position</th>
<th>Sender speed</th>
<th>Sender direction</th>
<th>Estimated RTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(101)</td>
<td>(13 bits)</td>
<td>(8 Bytes)</td>
<td>(4 Bytes)</td>
<td>(1 Byte)</td>
<td>(2 Bytes)</td>
</tr>
</tbody>
</table>

Fig. 4: Structure of the proposal optional headers for Route Advertisement to carry metric information.
index the MN uses information from the most recent RAs it has received from gateways. The first step is to normalize the metrics based on a Simple Additive Weighting. Positive metrics (those for which higher is better, i.e., gateway throughput and path stability) are normalized as:

\[
\text{normF}(M_i) = \frac{M_i - M_{\text{min}}}{M^{\text{max}} - M_{\text{min}}} \quad (6)
\]

where \( M_i \) is the most recent value from gateway \( i \), \( M^{\text{max}} \) is the maximum value of that metric across all gateways and \( M_{\text{min}} \) is the minimum. Similarly, negative metrics (e.g., hops, traffic load) are normalized as:

\[
\text{normN}(M_i) = \frac{M^{\text{max}} - M_i}{M^{\text{max}} - M_{\text{min}}} \quad (7)
\]

In general, the gateway index is a weighted sum of the individual normalized metrics, i.e.:

\[
D_i = \sum_{m \in \{\text{H, C, L, U}\}} w_{\text{m}} \cdot \text{normP}(m) + \sum_{m \in \{\text{H, C, L, U}\}} w_{\text{m}} \cdot \text{normN}(m) \quad (8)
\]

The effectiveness of the gateway index in identifying the best gateway depends on the weights chosen. To evaluate the architecture different combinations of metrics are considered. Hops to gateway (H) is used as a baseline in this study. The hop count is commonly used in routing...
Table 1: Prioritized weights for gateway selection metrics that depend upon application and user requirements

<table>
<thead>
<tr>
<th>Set</th>
<th>App</th>
<th>Priority</th>
<th>Highest</th>
<th>High</th>
<th>Medium</th>
<th>Low</th>
<th>Unused</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VoIP</td>
<td>Delay</td>
<td>(w_d)</td>
<td>(w_{RT})</td>
<td>(w_H)</td>
<td>(w_L)</td>
<td>(w_{DR})</td>
</tr>
<tr>
<td>2</td>
<td>VoIP</td>
<td>Cost</td>
<td>(w_{C})</td>
<td>(w_{RT}, w_{CI})</td>
<td>(w_{Hi}, w_{Li})</td>
<td>(w_{TH}, w_{T})</td>
<td>(w_{RT}, w_{CI})</td>
</tr>
<tr>
<td>3</td>
<td>VoIP</td>
<td>Both</td>
<td>(w_{B})</td>
<td>(w_{RT}, w_{BT})</td>
<td>(w_{BI}, w_{BT})</td>
<td>(w_{TH}, w_{BT})</td>
<td>(w_{RT}, w_{BT})</td>
</tr>
<tr>
<td>4</td>
<td>Video</td>
<td>Throughput</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
</tr>
<tr>
<td>5</td>
<td>Video</td>
<td>Cost</td>
<td>(w_{C})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
</tr>
<tr>
<td>6</td>
<td>Video</td>
<td>Both</td>
<td>(w_{B})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
<td>(w_{VT})</td>
</tr>
</tbody>
</table>

Table 2: Default and range of parameter values used in simulations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of gateways</td>
<td>5</td>
</tr>
<tr>
<td>Gateway separation</td>
<td>1000 m</td>
</tr>
<tr>
<td>Gateway uplink capacity</td>
<td>4 to 14 Mb sec(^{-1})</td>
</tr>
<tr>
<td>Gateway RA interval</td>
<td>100 ms</td>
</tr>
<tr>
<td>Gateway charge rate</td>
<td>0.2 to 1.2 Baht/MB</td>
</tr>
<tr>
<td>Highway lanes</td>
<td>2</td>
</tr>
<tr>
<td>Highway length</td>
<td>4000 m</td>
</tr>
<tr>
<td>Vehicle density</td>
<td>0.01 to 0.05 vehicle m(^{-1})</td>
</tr>
<tr>
<td>Vehicle speed</td>
<td>80 to 120 km hr(^{-1})</td>
</tr>
<tr>
<td>Session data rate</td>
<td>64 to 512 kb sec(^{-1})</td>
</tr>
<tr>
<td>Sessions per vehicle</td>
<td>0 to 2 sessions</td>
</tr>
<tr>
<td>Number of 3G capable vehicles</td>
<td>20% of all vehicles</td>
</tr>
<tr>
<td>Handover threshold, (Tr)</td>
<td>20%</td>
</tr>
</tbody>
</table>

Performance evaluation: To demonstrate the effectiveness of the proposed gateway selection algorithm and to illustrate the tradeoffs in the different metrics, a highway network is simulated in MATLAB with the following performance metrics collected:

- Application throughput as determined by the load on the gateways
- Signalling overhead incurred by information collection (i.e., RAs), exchange of information between gateways and handovers (e.g., Mobile IPv6 Binding Updates). In determining the total signaling overhead packets sent across the Internet (\(W_{so}\)), sent across the vehicular network (\(W_{sv}\)) and sent within the vehicle (\(W_{sv}\)) are weighted differently. Namely, \(W_{so} = 1\), \(W_{sv} = 2\) and \(W_{sv} = 0.1\)

The objective is to show how the gateway selection algorithm performs when using different metrics. The metrics used in this paper are: hops only (STD), Gateway throughput only (P1), Traffic load only (P2); RET only (P3), Path stability only (P4); A combination of hops, financial cost, gateway throughput, load and RET, weighted according to a set chosen from Table 1 (P5); And a combination of stability, financial cost, gateway throughput and load, weighted according to a set chosen from Table 1 (P6). These metrics are considered in different scenarios. In particular the impact of number of gateways and the uplink capacity of those gateways is analyzed. Also the density of vehicles on the highway and the charge rate is varied. Key parameter values are listed in Table 2.
Fig. 6: Average application throughput/network offered load versus gateway throughput capacity, with weighting function Set 4, fixed gateway charge rate.

Fig. 7: Average application throughput/network offered load versus difference in gateway throughput capacity, with weighting function Set 4, fixed gateway charge rate, capacities High-Low-High-Low-High

Fig. 8: Average application throughput/network offered load versus difference in gateway throughput capacity, with weighting function Set 4, fixed gateway charge rate, capacities Low-High-Low-High-Low

Figure 6 shows the application throughput (averaged across all nodes/sessions) as a percentage of the network offered load. The throughput depends upon the uplink capacity of the gateways. When all gateways have an uplink capacity of 12Mb/s, it is sufficient to support all application sessions all the time. For smaller gateway capacities, some sessions will not be fully supported, i.e., a gateway may be overloaded. Figure 6 shows how using different metrics impacts on application throughput when the gateway capacity is insufficient for all sessions. Using multiple metrics (P5 and P6) offers a 5-10% increase over using only one metric. There is a smaller increase in using RET or load as the metric compared to the standard metric of hop count, but this increase on its own may not outweigh the extra complexity of using RET or load (signaling overhead will be shown shortly).

Figure 7 and 8 are similar to Fig. 6, except the gateways have varying capacities. In Fig. 7 the five gateways have capacity of High-Low-High-Low-High (i.e., first gateway has higher capacity than second gateway). The different between the High and Low capacities is plotted on the x-axis. In Fig. 8 the capacity pattern is Low-High-Low-High-Low. These arrangements are chosen to demonstrate that the gateway selection algorithm is feasible when there are varying gateway capabilities. Both sets of results show again that using multiple metrics offers increase performance against using a single metric. Also, from Fig. 6, 7 and 8 it is evident that using only gateway throughput (P2) is not an appropriate metric (it often performs worse than using the simpler hop count).

Figure 9 shows that an increased vehicle density (i.e., more vehicles in the fixed area) leads to lower application throughput. Once again combining multiple metrics (P5 and P6) delivers 5 to 10% more throughput than the individual metrics.

The financial cost is an important non-performance-related metric. Figure 10 demonstrates how the proposed
J. Name

Fig. 10: Financial cost proposed/standard algorithm versus difference in gateway charge rate, with weighting function Set 5, gateway capacity 8Mb/s, gateway charge rates Low-High-Low-High-Low

Fig. 11: Average application throughput/network offered load versus difference in gateway throughput capacity, with weighting function Set 6, fixed gateway charge rate, capacities High-Low-High-Low-High

Fig. 12: Ratio of signaling overhead of proposed algorithms compared to standard versus number of gateways

algorithm can incorporate the financial cost. For metrics P5 and P6 the financial cost is now considered as a primary factor that is Set 5 is used for the weights. All gateways have the same capacity (8 Mb sec$^{-1}$), but different charge rates (High-Low-High-Low-High). Figure 10 shows the total financial cost incurred relative to the standard algorithm (hops only) for varying differences between gateway charge rates. The lower the financial cost the better. As can be seen using the financial information in the gateway selection (P5 and P6) can lead to a decrease in total cost of around 20% compared to P2 and P4.

The preceding results demonstrate that the proposed gateway selection algorithm can improve application throughput and/or financial cost by using multiple metrics (Fig. 11). The disadvantage of the proposed approach is the increase signaling overhead. This overhead mainly comes from broadcast multi-hop RAs that are used for MR/MN to discover capabilities of gateways. Figure 12 shows the signaling overhead when the number of gateways is increased. The overhead is relative to that incurred with the standard hops to gateway selection algorithm. That is, STD incurs overhead of 1. Using metrics P1 to P6 increases the overhead by the factor shown. With five gateways, the worst case is a 30% increase in overhead. Note however that as this is a worst case performance, in general it will be less. The overhead should be tolerable for the application performance increase offered by the proposed gateway selection algorithm.

CONCLUSIONS

This study proposed an architecture for selecting the optimal gateway for a node within a vehicle in a VANET connected to the Internet. Assuming the vehicles create a multi-hop wireless network amongst themselves and a subset of vehicles offer shared 3G/4G access to roadside base stations (gateways), mobile routers onboard the vehicles should select the best gateway for Internet connectivity. Extensions to NDP are proposed to allow Route Advertisements to: (a) Traverse multiple hops and (b) Carry information about the gateway and path to gateway. A new gateway selection algorithm for the MR is designed; the algorithm considers multiple metrics. Functions for combining the metrics are recommended, including weights based on application (VoIP, streaming video) requirements. Simulation results show the gateway selection algorithm can improve application throughput when using multiple metrics, compared to the standard hop count metric. Extra signaling overhead incurred by the proposed protocol is tolerable. Future work includes extending the architecture to support load balancing between gateways, as well as analyzing the architecture in different scenarios (e.g., grid road networks).
ACKNOWLEDGMENTS

This research was supported by the Telecommunications Research and Industrial Development Institute (TRIDI), National Telecommunications Commission (NTC), Thailand, as well as Prince of Songkhla University and partially supported by the National Research University Project of Thailand, Office of Higher Education Commission.

REFERENCES


