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A Novel Protocol for Inter-vehicular Video Transmission

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A Novel Protocol for Inter-Vehicular Video Transmission

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Abstract

Over the recent years, there has been an extraordinary increase in the demand for real-time multimedia and infotainment services in vehicular domain. The availability of multimedia services over mobile phones and the tremendous success of low-cost Laptops have given rise to the expectation of providing multimedia services while on the move in vehicles. However, there are significant technological challenges in establishing continuous high-rate communication between the Internet/Multimedia server and the vehicles. The main problem is that it is difficult to provide direct communication between the server and the vehicles especially when the vehicles are moving at a very high speed. This paper proposes a novel Loss-based Hybrid-architecture-oriented Adaptive Multimedia Algorithm (LHAMA) protocol, which makes use of multiple hops to maintain the connection between the vehicle and the base station/server. LHAMA enables communication between the vehicles in a multihop fashion which in-turn allows high quality multimedia streaming. LHAMA ensures that even when the vehicles are moving at a high speed of 120 km/h, a throughout of up to 83% of the maximum value is achieved.

1. Introduction

Multimedia streaming requires seamless and high rate continuous connection between the multimedia server and the end-users. Additionally, the quality of service of the transmission mechanism needs to be maintained in order to have high throughput, and importantly, high end-user perceived quality. When trying to achieve this wireless network involving a mobile device, problems can occur. In a simple two node scenario where the client is mobile, as shown in Fig. 1, the client will always move relative to an access point and as a result will not always be in range of the server.

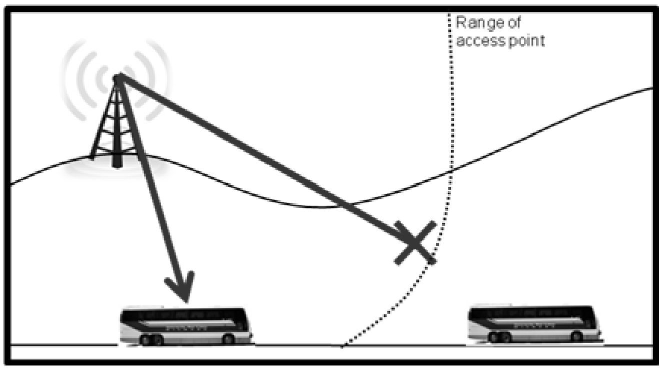

Fig. 1 Mobile client moving out of range of base station

This paper investigates a plausible solution by having multiple hop communication between the server and the vehicles (clients). When the client moves out of range of the base station, by hopping the packets to the other vehicles in the network, the connection can be maintained seamlessly. The other vehicles in the network will act as proxy servers in order to hop the multimedia packets to the client, as shown in Fig. 2. In this context, this paper proposes a **client-server Loss-based Hybrid-architecture-oriented Adaptive Multimedia Algorithm (LHAMA)**, a novel protocol for multi-hop adaptive multimedia streaming and evaluates its performance using various network topologies and simulations.

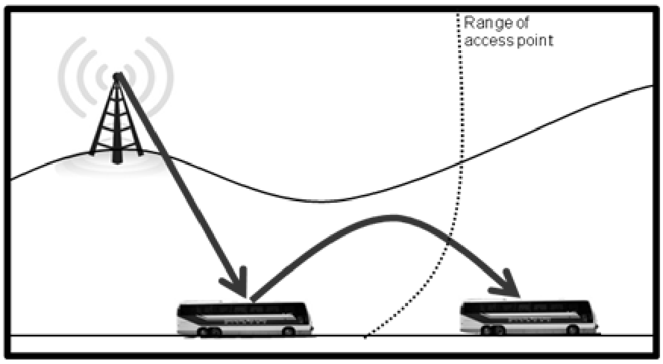

Fig. 2 Base station maintaining connection with a client using a one-hop solution

2. Related Work

There has been much related work done in this research area. A paper by Franz et.al [1] used a similar multi hop solution (ad-hoc) to keep vehicles in range of an access point in a wireless network. In a similar paper by J. Ott and D. Kutscher [2], ad-hoc routing was used as a solution to inter-vehicle communication, where vehicles could communicate to each other about road or traffic conditions.

Similar papers such as those by T. Casey, D. Denieffe and G.-M Muntean [3] have looked at the effect node velocity has on the performance of wireless networks which is also very relevant to this field of study.

There are many other papers that utilise this multi-hop solution but very few deal with the idea of multimedia streaming in these ad-hoc networks. The idea of implementing multimedia distribution in a mobile wireless network is what makes the protocol discussed in this paper a new and exciting idea.

3. LHAMA

This section proposes the novel LHAMA protocol and provides a detailed explanation.

3.1 The Protocol

The novel protocol relies on a client-server Loss-based Hybrid-architecture-oriented Adaptive Multimedia Algorithm (LHAMA), which combines the loss-based additive increase multiplicative decrease adaptive multimedia delivery scheme and the Dynamic Source Routing (DSR) protocol.

The DSR protocol is a simple routing protocol designed specifically for use in multi-hop wireless ad-hoc networks of mobile nodes [4]. DSR relies on two mechanisms that work together to discover (Route Discovery) and maintain (Route Maintenance) routes in an ad-hoc network [4].

Route Discovery is used when a server node wishing to send packets to a client discovers a route to the destination node. Route discovery is only used when one node wishes to send packets to a client and does not already know a route to the destination node.

Route Maintenance is the mechanism by which the server node is able to detect, while sending packets to a destination node using a source route, if the network topology has changed such that it can no longer use its current route because a link in that route is broken. Once Route Maintenance indicates a route is broken, the server node can use any other route to the destination node it already knows or it can call Route Discovery again to find a new route.

LHAMA uses multiple hops to keep in contact with the client as stated before, making use of the DSR protocol. By using the two mechanisms in DSR, multimedia packets take the shortest route possible to the client. When a shorter route becomes available the protocol adapts and uses the new shorter route to the client. Also, as soon as a route is broken, for example when a node moves out of range, the protocol adapts to find a new route.

The applications that deploy LHAMA are loss based adaptive server and client multimedia applications: sMmApp and cMmApp. These applications use an adaptive five rate media scaling method [5]; the higher the scale value - the higher multimedia bitrate. When the server and client establish a connection, the server starts with the lowest transmission rate (and scale level) and changes it during the session according to what the client notifies. The client is responsible for monitoring network delivery conditions and determining the scale factor. For congestion control a simple periodical packet loss monitoring is used. If congestion is detected the client reduces the scale to half and notifies the server. If no packet loss is detected the client increases the scale level by one and notifies the server. The server performs the client-requested changes in the scale value and consequently in the multimedia transmission rate.

3.2 Development

The main work done in the development of the protocol was in the creation of the client-server loss-based adaptive multimedia algorithm, which involves a server application deployed on the base station and a client application, located at the mobile client (vehicle).

The adaptive multimedia applications rely on a modified UDP agent which was enhanced with additional features in order to support multimedia delivery. These new features included:

- Enabling multimedia packet reception and delivery.
- Segmentation and reassembly of data packets
- Enabling prioritisation for multimedia delivery

The client-server application and the underlying agent were developed and a model was created in order to enable performance evaluation.

4. Testing and Performance Analysis

This section presents how the performance of the proposed LHAMA protocol was evaluated. An NS-2 model was built for LHAMA and deployed in four scenarios as indicated below. LHAMA's performance was tested by looking at the effect hop count; range and mobility have on multimedia delivery aspects such as throughput and packet loss.

Network Simulator version 2 (NS-2) is a discrete event simulator targeted at networking research [6]. NS was built in C++ and provides a simulation interface through OTcl, an object oriented dialect of Tcl. The user describes a network by writing OTcl scripts and NS simulates the topology with specified parameters.

The outputs of these simulations were used to look at the performance of the novel protocol. By tracing the output of the simulations the topology could be animated using network animator (nam) to give a visual representation of the network.

By using awk scripts to analyse the trace files the results of the simulations could be plotted using xgraph. Alternatively, the results could be written to a Microsoft Excel file and plotted from there.

4.1 Scenarios

Scenario A simulates a three-hop scenario to keep the client in range after it has passed the access point.

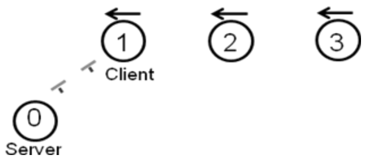

Fig. 3.1 Network topology A

Scenario B entails a three hop scenario to establish connection with the client before it reaches the access point.

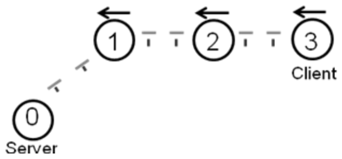

Fig. 3.2 Network topology B

Scenario C is a five hop connection to establish communication with the client before it reaches the base station.

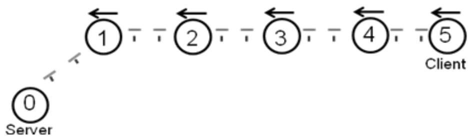

Fig. 3.3 Network topology C

Scenario D involves combining scenario A and B. Nodes leading and trailing the client will allow the server to establish connection with the client before it reaches the access point and retain connection once it has passed.

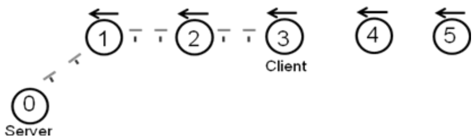

Fig. 3.4 Network topology D

4.2 Hop Count Study

The novelty in the development of the LHAMA protocol is the implementation of multiple hops. Hence, the effect the hop count has on the packet loss and throughput is a very important issue.

Figure 4 shows throughput results for the simulation of network topology A.

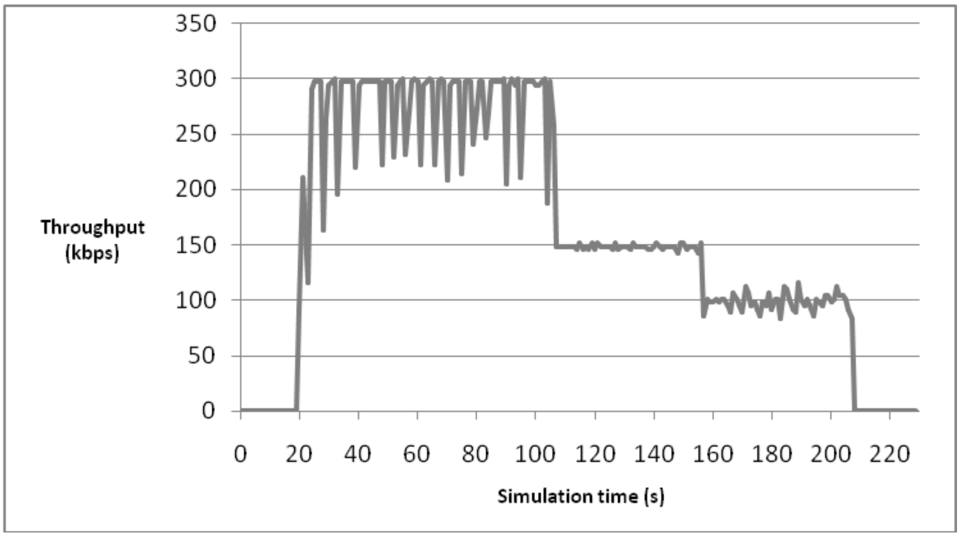

Fig. 4 Variation of Throughput with time for network topology A (mobility = 5 m/s)

Figure 4 shows a clear pattern for the variation of throughput with time. With a direct connection between server and client, the average throughput is 300 kbps. When LHAMA switches to the two-hop route by having the communication from the server to node 2 to the client, the throughput to the client is halved. On similar lines, when the 3^{rd} hop is added, the average throughput to the client falls to $1/3^{rd}$ of the original value. This is further corroborated by the results shown in Figure 5. Network topology C shows a 5-hop scenario between the server and the client. It can be seen that in case of a 5-hop system, the average throughput to the client is only $1/5^{th}$ of that of a single-hop server-client route. Hence, the above could be generalized and stated that over an '*n*'-hop system between the server and the client, the average throughput over each hop at any instant of time would be about $1/n$ times the average throughput under a direct server-client connection.

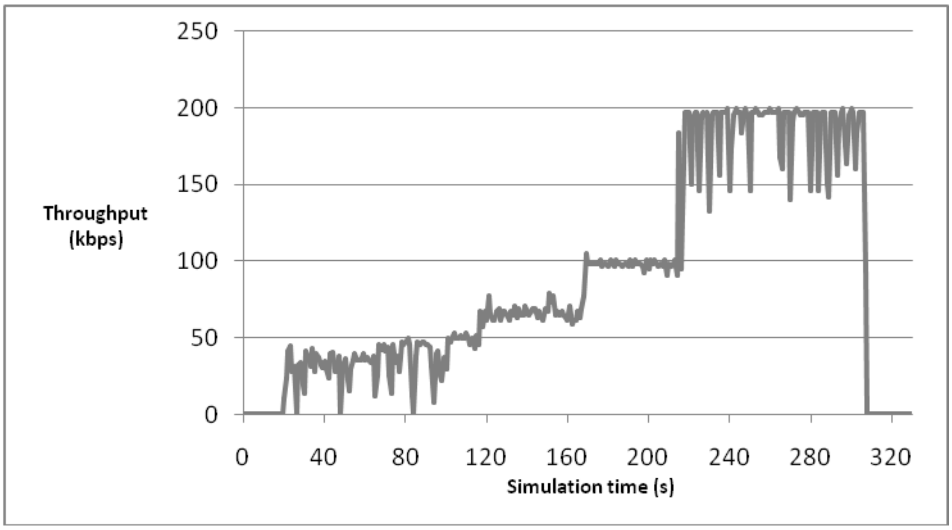

Fig. 5 Variation of throughput with time for network topology C (mobility = 5 m/s)

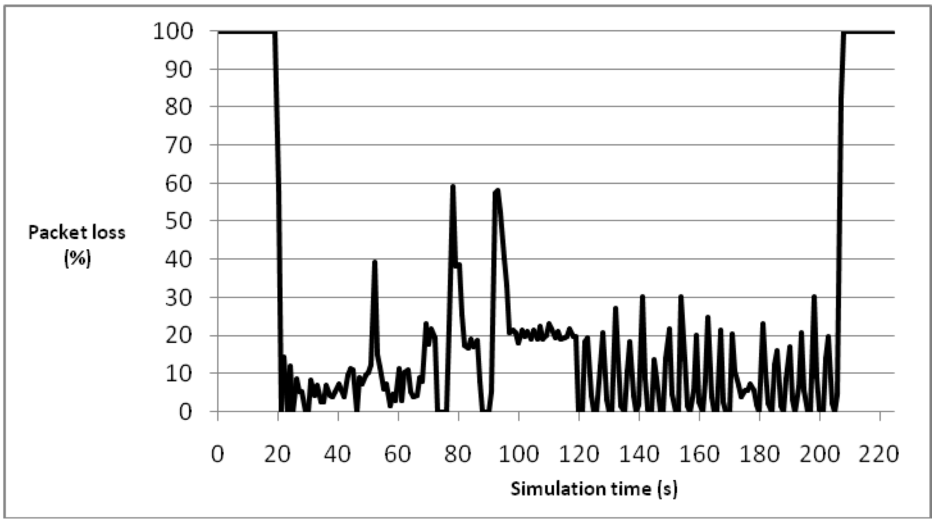

Fig. 6 Variation of packet loss with time for network topology B (mobility = 5 m/s)

Fig. 6 shows packet loss results for the simulation of network topology B. It can be observed from Fig. 6 that when *n*=3 the packet loss is less than when *n*=2. This is because when the transmission is altered from a 3-hop scenario to a 2-hop one, the server temporarily shares its packets between the two routes. Hence, when *n*=2, the bandwidth is pushed to its maximum possible capacity and the packets are subsequently dropped.

4.3 Client Range Study

The main reason for using multiple hops is to effectively increase the range of the end-to-end communication. Fig. 7 demonstrates the benefits obtained by using the novel LHAMA protocol over the single-hop scenario. In the topology D, since there are nodes on either side of the client, the server will be able to establish communication with the client sooner, which it would not be able to do in a direct communication method.

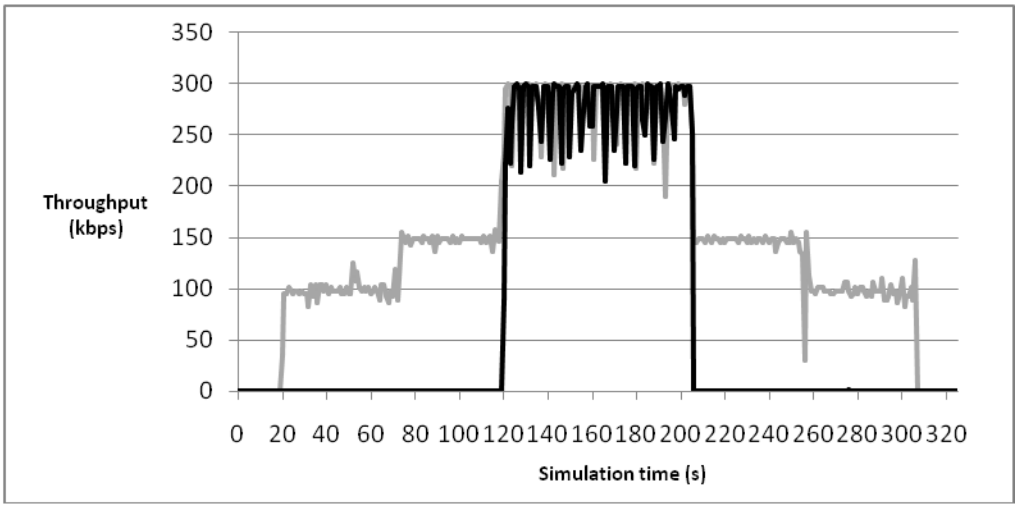

Fig. 7 Variation of throughput with time for network topology D (mobility = 5 m/s)

Fig. 7 shows how much longer the client would be kept in range when using LHAMA. The black line shows how long the client would be kept in range when just a single node is present. The grey line shows how long the client is kept in range when using LHAMA. The client stays in range for the duration it would on its own, in addition to the time it takes for the other nodes to move out of range. As can be seen in Fig. 7, the time duration during which the connection remains established is tripled.

However, as explained in section 5.2, with each new hop, the throughput gets reduced and the packet loss increases.

4.4 Node Mobility Study

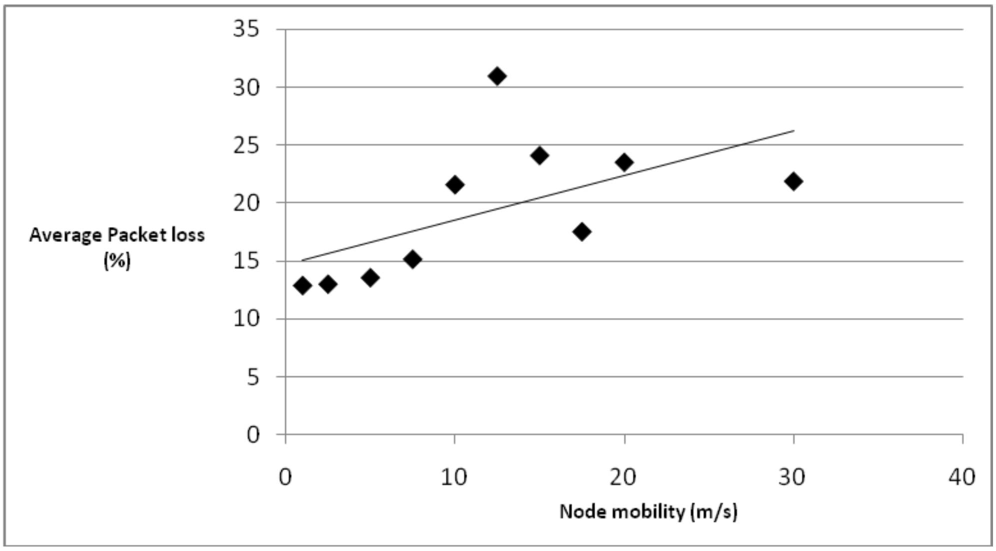

Fig. 8 Variation of Packet loss with node mobility for network topology A

LHAMA is designed for high-speed mobile networks. Hence, the effect the speed of the wireless nodes has on the system performance is extremely important. The performance of LHAMA was tested under several network topologies using different node velocities. For each velocity, the average packet loss for the duration during which the server and client were in contact was calculated. Fig. 8 shows the effect node mobility has on packet loss for network topology A. It can be seen that the packet loss increases linearly with an increase in the node velocity. However, even when the nodes are moving at speeds of 30 m/s (approx 120 km/h) packet loss is still only ten percent more than when the nodes are stable.

Similarly, it can be observed from Fig. 9 that the throughput decreases linearly with an increase in the node velocity. However, even when the nodes are moving at 30 m/s (approx 120 km/h) throughput is still 83% of overall throughput when the nodes are stable.

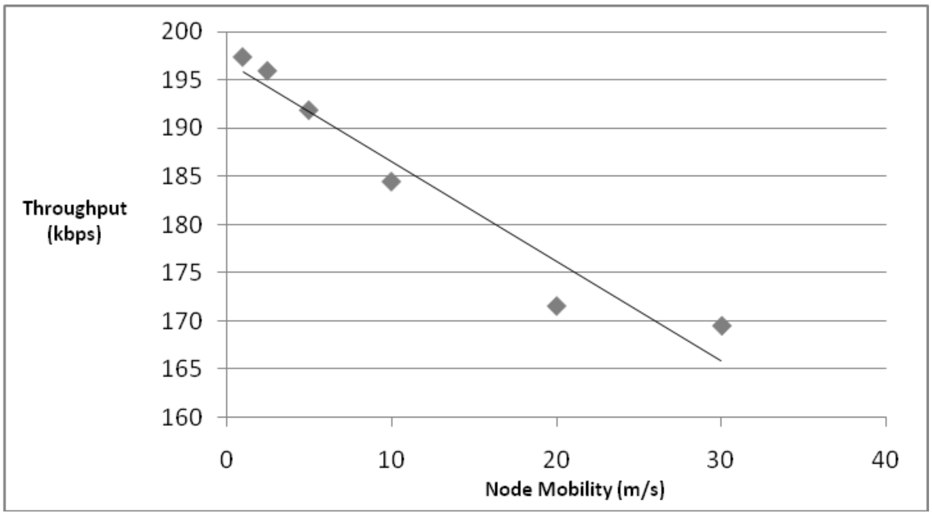

Fig. 9 Variation of throughput with node mobility for network topology A

5 Conclusions and Future Work

This paper proposes a novel unicasting protocol, LHAMA – Loss-based Hybrid Architecture Multimedia Algorithm. The main benefit of LHAMA is that it ensures the connectivity between different nodes (vehicles) and with the Internet/server even when the vehicles are on the move. Hence, the wireless devices in the vehicles can communicate with each other and importantly, can watch streaming multimedia while on the move.

As shown earlier, LHAMA's performance holds up extremely well under an increase in node velocity. Even under node velocity of 30 m/s throughput is maintained at 83% of its capacity under a node velocity of 0 m/s. Similarly, packet loss is only increased by 10% when node velocity is increased to 30 m/s as compared with stable nodes (0 m/s).

The only drawback at this stage is that the throughput of LHAMA degrades significantly with an increase in the number of multiple hops. Notably, for an '*n*'-hop system, the achievable throughput is only 1/*n* times as compared to a single-hop direct transmission between the server and the client.

LHAMA still needs considerable work before it could be applied in the real-world for multimedia streaming. Hence, the next task is to introduce spatial reuse of resources in the design of LHAMA that would increase the throughput of the network, using the same given resource. It is expected that with the exponentially decreasing power delay profile, the spatial reuse would not introduce significant interference while at the same time, increasing the network throughput. Further, in order to test its feasibility, the LHAMA protocol would be tested in a real-world environment by implementing it over a Motorola WAP 400 access point used in WiMAX [7].

ACKNOWLEDGMENTS

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