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Advanced Travel Information System in Heterogeneous Networks

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***Abstract*—**In order to achieve better road utilization and traffic efficiency, there is an urgent need for a travel information delivery mechanism to assist the drivers in making better decisions in the emerging intelligent transportation system applications. In this paper, we propose a relayed multicast scheme under heterogeneous networks for this purpose. In the proposed system, travel information consisting of summarized traffic conditions, important events, real-time traffic videos, and local information service contents is formed into layers and multicasted through an integration of WiMAX infrastructure and Vehicular Ad hoc Networks (VANET). By the support of adaptive modulation and coding in WiMAX, the radio resources can be optimally allocated when performing multicast so as to dynamically adjust the number of data layers received by the users. In addition to multicast supported by WiMAX, a knowledge propagation and information relay scheme by VANET is designed. The experimental results validate the feasibility and effectiveness of the proposed scheme.

***Keywords*—**Intelligent Transportation Systems, Relayed Multicast, WiMAX, Vehicular Ad hoc Networks (VANET).

I. INTRODUCTION

CONNECTING intelligent vehicles with one another and with their driving environment is a growing trend in ITS [1]. With the increasing traffic density, a travel information multicasting system that provides drivers with real-time information can substantially improve road safety and traffic efficiency.

The system architecture for the proposed advanced travel information multicasting system is illustrated in Fig. 1. Traffic surveillance videos are collected via roadside cameras. Intelligent Transportation Service (ITS) center processes the collected data to summarize traffic conditions and detect events of interest. In addition to the traffic conditions, the drivers can also choose to see the real-time streamed traffic surveillance videos of a certain location. In [2], scalable geo-referenced videos and geographic information are transmitted to GPS-guided vehicles, which inspire the feasibility of multicasting real-time travel information data to mobile stations. Contents of local information services such as places of interest, hotels, restaurants, gas stations or parking lots can also be multicasted through the infrastructure. Under such circumstances, the multicast contents can include both pure text and multimedia data. In order to use the channel efficiently, the multicast contents are arranged into layers and utility-based resource allocation is applied at WiMAX base station (BS). Users receive a certain number of layers of information according to their needs and available channel conditions. Furthermore, an auxiliary knowledge propagation and information relay mechanism is designed to support users that require more information but with unsatisfactory channel conditions.

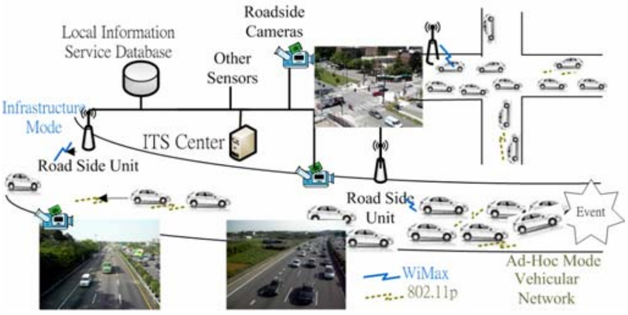

Fig. 1 System framework

There have been a lot of existing wireless ad hoc multicasting technologies. However, the solutions for multicasting multimedia contents in mobile ad hoc networks remain limited. It is very challenging for the vehicular ad hoc networks to transmit real-time streaming data because the vehicles are mobile and dynamic routes need to be constructed at all times. Some recent works try to solve a subset of the problem with vehicular ad hoc networks for real-time streaming data. Guo et al. [3] presented a vehicle-to-vehicle live video streaming mechanism using a store-carry-and-forward approach to transmit video data in a partitioned network environment and incorporating a signaling mechanism to continuously trigger video sources to send video data to receivers. However, they focus only on the scenario of multiple mobile sources streaming video to a single mobile receiver, which does not suit our application. Killat and Hartenstein [4] presented an accident prevention application (APA) based on vehicular ad hoc networks and explained how

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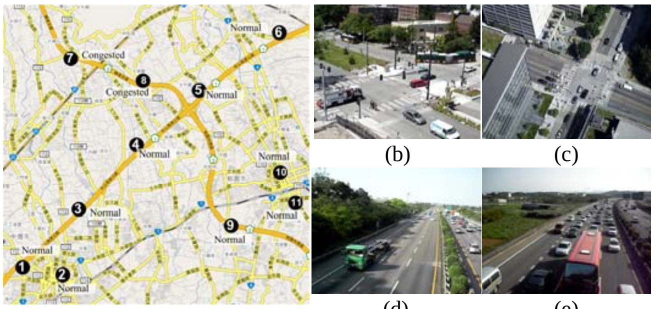
an APA could be designed and formalized with the help of Markov Reward Processes. However, no multimedia data is involved in their application. Very few works addressed the relay mechanism in heterogeneous networks, but actually heterogeneous networks with both infrastructure-based and ad hoc technologies provide more promising solutions for real-time multimedia contents in travel information delivery applications in wide areas. Hauge [5] proposed a heterogeneous cellular and ad hoc network architecture, which assumes 3G infrastructures instead of WiMAX. With their assumption of 3G infrastructures, they did not mention layered or scalable data concept in their work, either. The rest of this paper is organized as follows. The relayed multicast scheme for information delivery in heterogeneous networks is presented in Section II. The experimental results are explained in Section III. Finally, a conclusion is made in Section IV.

II. Relayed Multicast Scheme for Travel Information Delivery

In this section, we present a framework aiming at delivering layered travel information to users effectively through multicast with auxiliary knowledge propagation and information relay support. The framework is built based on the emerging IEEE 802.16e for WiMAX and IEEE 802.11 family standards. In [2], the scalable geographic information data is divided into layers of roads, buildings, topographical and administrative districts. The multicast contents are also divided into layers in our application. Users can select between two types of information contents. One type of information content includes the traffic conditions and local information attached to the map. The other type contains the real-time streamed live traffic videos of specific locations. Through the optimized resource allocation mechanism of WiMAX described in subsection II A, the system ensures that every mobile station (MS) can receive the base layer of the map and summarized traffic information. Other layers can be received only by a subset of users with a certain channel quality requirements. For users that cannot receive a certain layer due to unfavorable channel conditions but would like to obtain the desired information, an auxiliary knowledge propagation and relay mechanism is designed to relay the information to the users, which is explained in subsection II B.

As the example shown in Fig. 2, when a user receives the map and summarized traffic conditions (see Fig. 2 (a)), the user can choose to receive the live surveillance video of a certain location, as illustrated in Fig. 2 (b) to (e). For the information relay mechanism, there is no synchronization problem for type I information. However, for type II information, the base layer and the enhancement layer of the live video must be synchronized. If the enhancement layer is obtained through the information relay mechanism, a delay would be incurred. Such a delay is normally tolerable for this application. Therefore buffering can be used to synchronize the layers of the traffic video.



(a) Summarized traffic conditions at important road segments

(b) (c) (d) (e) (b)-(e) Live traffic video of a selected location

Fig. 2 Example of multicast contents

A. Intelligent Multicasting

There has been positive anticipation that the IEEE 802.16e standard with the associated WiMAX forum could provide a promising last mile wireless broadband technology. The high bandwidth and broad coverage range of WiMAX combined with its multicast support make it suitable for the applications of transmitting layered geographic travel information data and live traffic video. However, the quality of the signal received by a mobile station (MS, also referred to as Subscriber Station (SS) in some references) can vary over time in a wireless environment. Therefore, the modulation and coding schemes have to be adaptive. Furthermore, the channel is shared with other services, so the overall amount of bandwidth manageable under the service is limited. An intelligent mechanism of managing multicast resource of infrastructure is a key step of successful delivery.

A utility-based resource allocation scheme is adopted for efficient multicasting [6], [7]. Given N MSs $\{MS_k, k = 1,\ldots, N\}$, the goal is to dynamically adjust the burst profile for each multicast layer in order to maximize the total utility, $U = \sum_k U_k$, subject to the total resource B pre-allocated to multicasting service in base station BS. For each multicast data layer, a utility $u_{c,l}$ is assigned for the *c*-th channel and the *l*-th layer. Therefore U_k equals to $\sum_{c(k),l(k)} u_{c,l}$, which is the summation of utility of all received layers at MS_k. The process first selects proper burst profiles serving base layers to all MSs subscribing the channel. For enhancement layers, their burst profiles are assigned according to the ratio of total utility gain to extra resource consumed, which can be expressed as $\Delta U / \Delta B_c$. Depending on the number of MS in favorable or unfavorable channel conditions, the utility gain ΔU can vary and the best one among all layers will be picked until B is fully used up. This effective resource allocation can be performed every frame for the best channel usage. After the process, resources allocated for travel information multicast service is optimized at

WiMAX BS as illustrated in Fig. 3 of a downlink sub-frame. The multicast and broadcast service (MBS) region is allocated for the multicast contents. Base layers with more robust modulations would cost more resources. The enhancement layers are under faster modulations intended only for a subset of users with better channel qualities. Therefore at the client side, all MSs receive at least base layer of channels subscribed, while some at good channel quality can receive more and be capable of relaying the information to other users using the mechanism described in the next sub-section.

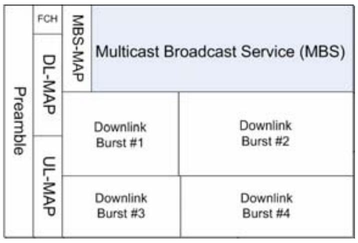


Fig. 3 A WiMAX downlink sub-frame with its MBS region

B. Knowledge Propagation and Information Relay Mechanism

Due to unfavorable channel qualities, some MSs might be able to receive only the base layer. For MSs who need more information but cannot receive the enhancement layers, an auxiliary information relay mechanism is designed to enable the desired information flow from those who already have it to those who cannot receive it. The beacon messages sent in the VANET is used to propagate the knowledge of ownership of information. Beacon messages are sent regularly by a set of MSs in a VANET for the MSs to learn the neighboring relationship. It is legitimate to request all the MSs in the VANET to send beacon messages regularly. In the proposed information relay mechanism, we utilize the frame body of the beacon messages to propagate some information. MSs could indicate how many layers they are able to receive in the beacon messages. For an MS that can only receive the base layer, it can check the beacon messages received from its neighbors. If it finds out that one of its neighboring MSs has the enhancement layers it desires, it can request the neighbor to broadcast the enhancement layer.

Each MS keeps a neighbor list, a children list, and a parent. The information about the number of children it has, the number of enhancement layers it is currently subscribing, and the relay counts to the source are exchanged among mobile stations through beacons. Once an MS which is not receiving the enhancement layers (MS1) finds out one of its neighbors has the enhancement layer, it will send out a REQ_RELAY message to the neighbor (MS2). Once MS2 receives REQ_RELAY, an ACK_RELAY message will be returned to MS1. MS1 then broadcasts an UPDATE message to update its most recent information among its neighbors. This is to prevent the slower update rate using beacon messages. The REQ_RELAY, ACK_RELAY, and UPDATE messages are shown in Fig. 4.

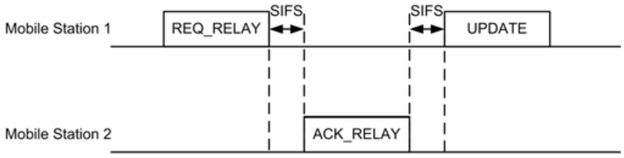


Fig. 4 Messages REQ_RELAY, ACK_RELAY, and UPDATE

A relay check procedure and a relay improvement procedure are designed for the VANET. The relay check procedure is for the mobile stations without enhancement layers to find a suitable neighbor to serve as its parent node. And the relay improvement procedure is for the mobile stations already getting enhancement layers from others to improve the route. The flow chart in Fig. 5 and Fig. 6 show how the relay check procedure and relay improvement procedure are performed.

There are two favorable criteria for choosing a neighbor as a parent node to relay the enhancement layer data. The first one is choosing the node with the smallest relay count, which denotes the number of times that the enhancement layer is relayed from the source to the mobile station. The second one is to choose the node with most children, i.e., the node with the largest children count. The latter criterion is to minimize the broadcasted information among the mobile stations. The relay check procedure chooses the parent for an MS in the following steps. If there is only one neighbor with the enhancement layer, the MS would send REQ_RELAY to this neighbor. If more than one neighbors have the enhancement layer, the MS would choose the one with the smallest relay count. If more than one neighbors have the same smallest relay count, the MS would compare the children count of these neighbors and choose the one with the largest children count. If more than one neighbors have the same smallest relay count and largest children count, the MS would choose the one with the best signal strength. For example, in Fig. 7, MS C is within the transmission range of MS A, MS B, and MS E. MS C would choose MS A as its parent, and send out REQ_RELAY to MS A. Compared with MS B, MS A has a smaller relay count. MS A has the same relay count with MS E, but MS A has a larger children count compared with MS E. Sending REQ_RELAY message is actually registering the information of the node into the children list of the parent node, so that other MSs can learn the most updated information about the routing and perform the parent choosing. The relay improvement procedure is for an MS to figure out if there are neighbors more suitable to be current parent by comparing the relay count and children count. If an MS finds a potentially better parent, it would send message to cancel the current relay and send REQ_RELAY to this potentially better parent.

In [8], the authors also used beacon messages to design a relay mechanism in ad hoc networks. However, there are several key differences between the proposed scheme and the work in [8]. In the proposed scheme, there is no particular source broadcasting to all MSs. The MSs would gather information in three ways, which are beacon message, UPDATE message, and the broadcasted data packets. The

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knowledge of selecting source MS is learned automatically. In [8], there is no request mechanism and all the MSs in the ad hoc networks have to deliver the relay data, which is more suitable in pure ad hoc network because it can lower the chances that the ad hoc networks become segmented. The proposed relay mechanism is more suitable for heterogeneous networks that consist of both VANET and wide-range infrastructure WiMAX because only MSs with inferior channel qualities need to request some of the information through the information relay mechanism. When relaying real-time data using the proposed mechanism, the chance of collision due to hidden nodes at broadcasting of our algorithm would also be smaller than [8] since unnecessary broadcasts from some of the MSs would be prevented.

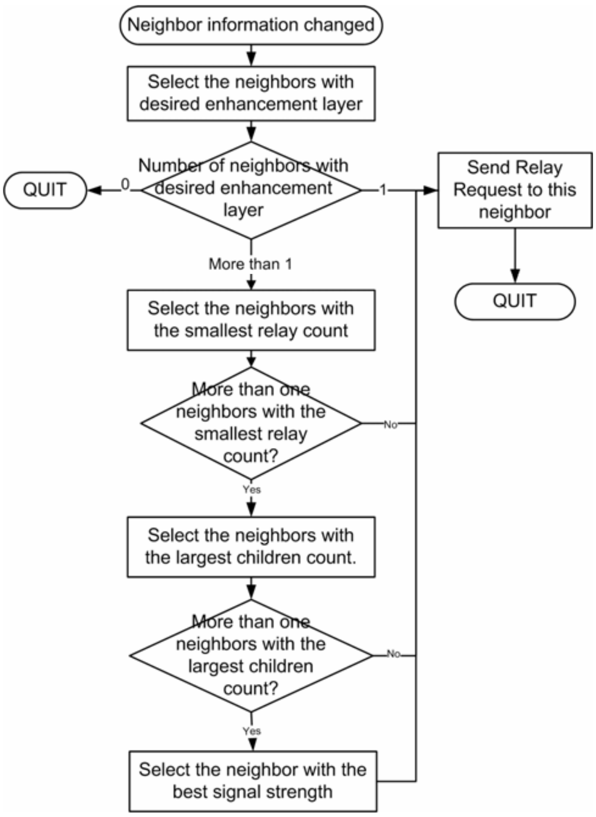


Fig. 5 Relay check procedure

III. Simulation Results

In this section, some simulation results are displayed to demonstrate the feasibility and performance of the proposed scheme. In the simulations, the streaming data is assumed to contain one base layer and one enhancement layer. The enhancement layer is 40 Kbps, i.e., 10 frames per second with 512bytes data in each packet. This experiment is to simulate the live traffic video transmission over a 10 Km x 10 Km geographic area. We assume that MSs within the central circular area of 2.5 Km radius can receive base layer and enhancement layer, and MSs outside this central circular area only receive base layer of the video. A simulator using C# is developed to simulate the relay of the enhancement layer. Two thousand MSs are uniformly distributed in the 10 Km x 10 Km area. Out of the 2000 MSs, 1480 MSs are located outside the central circular area of 2.5 Km radius and therefore cannot receive the enhancement layer. The transmission radius for each MS is set as 300 meters. The transmission rate is set to 1 Mbps.

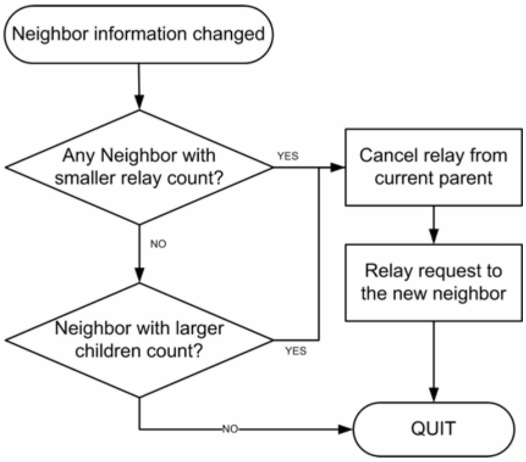


Fig. 6 Relay improvement procedure

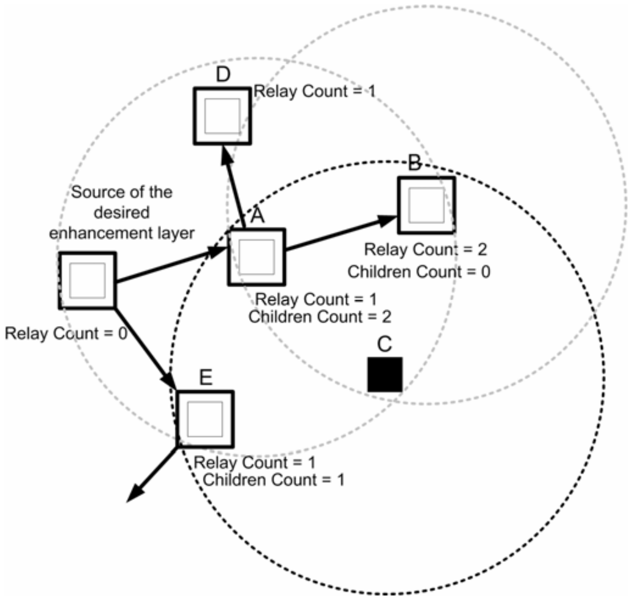
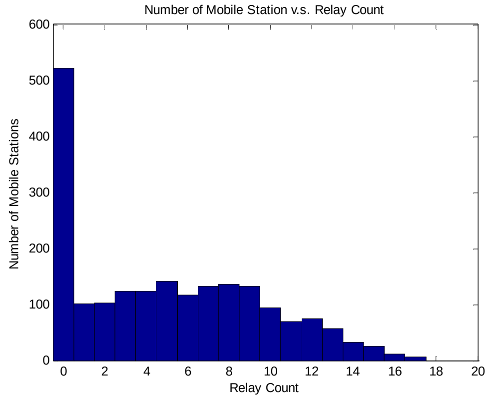
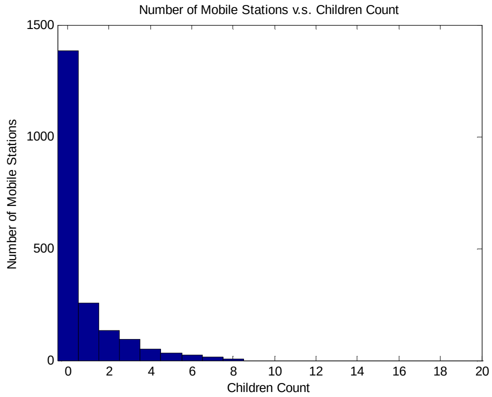


Fig. 7 Example of parent choosing for an MS

The histograms of relay count and children count in our simulation are shown in Fig. 8 (a) and (b), respectively. The relay count histogram shows that there are 520 MSs receiving the enhancement layer through the WiMAX broadcasting, and 1480 MSs rely on the relaying for the enhancement layer. The children count histogram shows that each enhancement layer packet would be rebroadcasted 615 times along the relay path.



(a)



(b)

Fig. 8 Histograms of (a) relay count and (b) children count

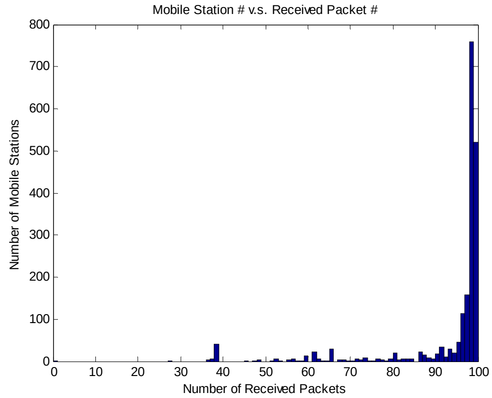


Fig. 9 Number of MS receiving the relayed packets versus the percentage of received packets

The statistics of the number of MS receiving the relayed packets versus the percentage of received packets are shown in Fig. 9. Out of 1480 MSs which are expecting the relayed enhancement layer of live traffic video, there are 1187 MSs that are able to receive more than 90% of the enhancement layer through the auxiliary knowledge propagation and information relay mechanism.

IV. Conclusion

A relayed multicast scheme under heterogeneous networks that can support the applications of transmitting essential traffic and travel information is presented in this work. The scheme aims at delivering layered information through wireless heterogeneous networks. The resource allocation of WiMAX can be optimized. The mobile stations fail to receive all layers can learn the layer information from neighbors and obtain the information through the auxiliary information relay mechanism using VANETs. The simulation results show that 80.2% of the mobile stations which fail to receive additional layers can regain more than 90% of the additional layer information through the proposed auxiliary information relay mechanism.

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