A Real-Time Subject Routing Protocol for MANETs

Marcelo Maia Sobral, Leandro Buss Becker

1Dept of Automation and Systems – Federal University of Santa Catarina (UFSC) CTC – Campus Universitário – Trindade – Florianópolis – SC – Brazil
{sobral,lbecker}@das.ufsc.br

Abstract. Applications using Mobile Ad Hoc Networks (MANETs) and requiring real-time guarantees must rely on predictable communication services. However, due to mobility and topology modifications, it is hard to keep updated the information about resource demands throughout the network. This impacts directly the real-time provisioning, both in the MAC and in the network layers, which must adapt themselves to network changes in a timely manner. Moreover, subject and content-based is widely used in such scenarios. The uncoupling among producers and consumers avoids the overhead in the network from keeping individual routes. This paper introduces the Real-Time Subject Routing Protocol (RTSR), a subject-based routing protocol that uses dynamic resource reservation to implement a timely delivery of messages in MANETs.

1. Introduction

MANET applications requiring real-time guarantees include those composed by mobile autonomous nodes (vehicles/robots) that cooperate to perform common tasks. They rely on communication services to allow the nodes to interact explicitly. In the communication infrastructure, the real-time provisioning has to deal with the timely delivery of messages, and also with the modifications in resource demands caused by mobility and consequent topology changes. This impacts both the MAC layer, where messages must be transmitted in bounded time, and the network layer, where the routing must respect the time validity of messages. Regarding the routing problem, mobility of nodes can cause significant overhead both to keep routes updated and to manage the resource provisioning, which is necessary to provide the timely delivery of messages. Moreover, subject and content-based routing have been proposed to such applications, as described in [Carzaniga et al. 2004] and [Baldoni 2005] among others, because the uncoupling of producers and consumers avoids the overhead to keep individual routes throughout the network. Nonetheless, existing proposals focus mainly on disseminating abstractions and mechanisms, but still do not consider real-time properties.

To solve this problem this paper introduces the Real-Time Subject Routing Protocol (RTSR), a subject-based routing protocol with real-time properties. This protocol that is part of a project named Acervo, which aims to provide a real-time communication infrastructure for MANETs. The proposed protocol extends the proximity-driven routing proposed in [Baldoni 2005], which defines a content-based routing that does not depend on the network structure, and that delivers messages to the interested nodes in a best-effort manner. RTSR aims to provide the timely delivery inside regions around producers and consumers, which depend on the time requirements associated to each message. Subject-based routing is not so expressive as content-based routing, but it can provide a higher
knowledge about resource demands along the network. Using this approach it is possible to dynamically reserve resources to subjects within the regions where producers and consumers exist, and therefore to allow them to communicate in a timely manner.

2. Related Works

In [Carzaniga and Wolf 2001] Carzaniga highlights that content-based communications can be more efficient for applications with many-to-many communications, which reside in networks with volatile links, as for instance MANETs. In this case, communications are in fact driven by implicit addressing, and routers maintain subscription tables instead of address tables. Existing approaches explore different ways to implement a content-based routing. CBCB (Combined Broadcast Content Based) implements a content-based routing on top of a broadcast routing, by means of distribution trees [Carzaniga et al. 2004]. In [Yoneki and Bacon 2004] it is used ODMRP, a multicast routing protocol for ad hoc networks as a base for a content-based routing.

According to [Baldoni 2005], MANETs are dynamic environments that make it hard to maintain an efficient event dispatching infrastructure. Thus, it proposes a content-based routing named proximity-driven routing (PDR), which is independent of any event dispatching structure, where every node becomes a broker but there is no overlay dispatching network connecting them. In PDR, subscriptions are periodically sent by nodes and stored by their neighbors. Data messages are received and forwarded by nodes with matching subscriptions, using a prioritization mechanism based on the estimated proximity of destination nodes.

Although the proximity-driven routing is flexible regarding how messages are routed from producers to consumers, it works in a best-effort manner and therefore lacks real-time provisioning. As positive characteristics for its use in MANETs, there is its ability to disseminate messages without need of global information, consensus, or any kind of negotiation. But since some approximate knowledge of the network structure is shared during dissemination of subscriptions, this can be used to implement a dynamic resource reservation mechanism. If the routing is able to reserve resources according to existent published messages and matched subscriptions, a timely dissemination of messages may become feasible.

3. The RTSR Protocol

In RTSR, messages are disseminated in a timely manner and according to their subjects and existing subscriptions. The real-time properties of the protocol rely on resource reservations performed in the regions of the network where there are subscriptions. Resource reservation depends on HCT MAC, a TDMA-like MAC protocol with cyclic transmissions that can adapt to topology changes and proposed in [Sobral and Becker 2008]. Moreover, predicate-based filters announced with the subscriptions and stored along these regions are used to match messages and avoid unneeded use of resources. Therefore, this routing protocol aims to provide a timely dissemination service to different message classes. RSTR extends the proximity-driven routing [Baldoni 2005] presented in the previous section. However, this protocol lacks support to real-time communication. To solve this gap, RTSR proposes some modifications and extensions in the proximity-driven routing.
Messages with a given subject have a time validity defined by an attribute named *temporal range*. A message is discarded whenever its time validity expires. While the message time validity is not expired and there is at least one matching subscription, the message continues to be forwarded. Analogously, the temporal range of subjects influence the dissemination of subscriptions. A subscription has also a validity named *time distance* and constrained by the temporal range of its subject, which gives the time it takes to deliver the message to the nearest subscriber. When a node receives a subscription from a neighbor, it compares its time distance with the temporal range of the subject. Should this time be greater than the temporal range, the subscription is discarded, and consequently its propagation stops. Consequently, the temporal range of subjects define regions around publishers and subscribers, so that the communication between a publisher and a subscriber occurs if they are included in the intersection of their regions. The sizes of these regions depend on the available network resources, and thus a resource reservation mechanism is needed to enable the preservation of their temporal requirements. This is a major difference between RTSR and the proximity-drive routing, where subscriptions are disseminated all over the network, and messages are transmitted in a best-effort manner.

The dispatching of messages in RSTR is similar to the proximity-driven routing, except for the temporal aspect. Subscriber nodes announce subscriptions periodically to the subjects that they are interested on, and neighbor nodes receive and store subscriptions while they are valid. A subscription validity is proportional to its announcement period, and expires if not renewed within its validity. Stored subscriptions have an assigned list of subscribers, with their corresponding time distance and proximity values. This list is compared to the destination list contained in each received message, to enable the receiving node to verify if the message was sent to all subscribers in its range. Therefore, if a node receives a message with remainder time validity smaller than the time distance of the matching subscription, and the receiving node knows about other subscribers not listed in that or if some listed subscriber has a smaller proximity value, then the message is scheduled to be forwarded in the next opportunity. It is assumed that the mobility degree of the network has a reasonable high *link duration*, compared to the duration of the routing decisions, and thus the forwarding nodes of a given subject remain the same while topology does not change, what is named the *main path* of that subject. These nodes have smaller time distance values to the matching subscriptions, and already own enough resources to forward the messages. Finally, in the proximity-driven routing a node condenses its stored subscriptions in one predicate, that is announced as its own subscription, but in the RTSR subscriptions must be propagated while their time distances are not exceeded. Therefore, the condensed predicate must preserve the time distances of the original subscriptions.

The dynamic resource reservation defined by RTSR allocates bandwidth from the network and assigns it to subjects for exclusive use, or keeps it as spare bandwidth. An existing subscription in a node implies the reservation of enough bandwidth to forward the matched messages. Since alternative paths may exist for a subscription, but not all are useful, the resource reservation must occur only when a node actually decides to forward a message. This means a node that reserves bandwidth to a subject becomes a member of its main path. This impacts the decision about forward a message, because if still there are no reserved resources for its subject, and it is not possible to allocate more bandwidth, the
node will not forward it. On the other side, if a node has reserved resources to a subject, and has scheduled the transmission of a message but before that other node transmits the message, then the reserved bandwidth would be wasted. In that case, the bandwidth can be released to the network, or kept by the node as a spare resource.

The time distance of a subscription cannot be defined in the same manner of the time validity of messages. The elapsed time since the original transmission of a subscription is not the same as the time needed to send a matching message in the opposite direction. Actually, to compute the time distance a node needs to take into account the moment that it may send a matching message, and this depends on the reserved resources.

4. Conclusions and Future Work

This paper introduced RTSR, a Real Time Subject Routing protocol for MANETs that extends the proximity-driven routing proposed in [Baldoni 2005]. The proposed RTSR defines a dynamic resource reservation strategy to allocate bandwidth to message subjects, and thus to provide the dissemination of messages among publishers and subscribers in a timely manner. RTSR defines that the temporal range of a subject limits the dissemination of both its subscriptions and messages. A subscription delimits a region where a residing publisher can send messages that can reach its subscriber without exceeding their time validity. To enable the accomplishment of these time requirements, a node reserves bandwidth to a subject when it starts to forward its messages, according to the rules defined in the proximity-driven routing. But because nodes can move, routes and bandwidth reservation must adapt accordingly. A node with reserved bandwidth releases it as soon as it detects that the subscriber node is out of reach, or that another neighbor starts to forward it messages. Furthermore, nodes that release bandwidth may keep part of it to better respond to future necessities. This resource reservation strategy must be further investigated and validated with experiments with a prototype under development.

References


