The Study of Large-scale MANET Distributed Share Routing Protocol

Jing CHEN\textsuperscript{1,*}, Lu SUN\textsuperscript{1}, Ruonan LIU\textsuperscript{2}

\textsuperscript{1}College of Telecommunication Engineering, Air Force Engineering University, Xi’an 710077, China
\textsuperscript{2}The Department of Electrical Engineering and Computer Sciences, UC Berkeley, U.S.

Abstract

MANET routing protocol based on P2P has become a hot topic, but mainly researches on small or medium MANET did not take full advantage of P2P distributed share theory, there still exist detour and inefficiency problems. This paper presents large-scale MANET distributed share routing model based on P2P. It introduces layered mechanism based on network physical topology to enhance network scalability on the basis of cross-layer optimization, expands P2P distributed share strategy into MANET routing layer, publishes and shares multi-hop routing between the nodes, solved the detour problem in the previous algorithm. The experiment proves that this new routing protocol can greatly increase the large-scale MANET routing efficiency.

Keywords: P2P; MANET; Share Routing

1 Introduction

In recent years, after obtaining great success on the Internet and with rapid development of mobile communications, P2P systems are gradually extended to the Mobile Ad hoc Network (MANET). P2P MANET has become a popular research topic \cite{1}. However, P2P and MANET have many differences despite of their many similarities, which cause many challenges in the study of the intersection of these two areas \cite{2}. Leonardo B. Oliveira, etc, used Gnutella \cite{3} as a representative unstructured P2P network model and Chord \cite{4} as a structured P2P network model to place P2P applications directly on the MANET. This approach is consistent with the OSI layer model, but one jump on the P2P overlay network topology may correspond to multiple jumps on the physical topology, resulting in a decline in overall routing performance \cite{5}. Therefore, some researchers have proposed cross-layer (cross-layer) architecture and topology-sensitive technology, trying to solve the consistency issue of P2P application layer and MANET physical network \cite{6}.

With the increase in the number of the nodes, the cost of P2P logical topology maintenance goes overhead, and physical topology-sensitive control cost will also rapidly increase, rendering
the network impractical. This article puts forward Large-scale MANET Distributed Share Routing Protocol Based on Structured Peer Computing, abbreviated as LDSR. LDSR protocol is made suitable for large scale MANET environment on the basis of cross-layer optimization, by introducing tiered mechanism based on the actual topology of the network to improve network scalability; at the same time, introducing distributed routing resource sharing policies of P2P computing model, dynamic prediction of the shortest physical path, publishing and sharing of the above information between nodes can bypass problems in past algorithm improving the MANET routing efficiency.

2 LDSR Tiered Architecture

This articles made a new attempt using LDSR design: transplant resource publishing and sharing strategies on the application layer of the traditional P2P to MANET routing layer, publish and share between nodes the multi-hop routing information as a “routing resources”, so that nodes can search router using DHT, but end up communicate on the shortest physical path, namely stretch = 1 [7]. This effectively solves the structured P2P computing and misfit bypass problems brought about by the physical network topology. “Routing resources” here is fundamentally different from the publishing and sharing of resources in P2P system, the former is published and shared for network node to get routing information, the latter is published and shared for network nodes to gather information resource (including video, and sound, and file,); the former serves for network layer node routing, the latter serves for application layer resources sharing. As Multi-jump routing embodies MANET physical layer characteristics, publishing and sharing it as a resource represents distributed sharing theory of P2P computing model. Therefore, innovative concept of LDSR enables P2P cover layer and MANET physical network to be connected seamlessly together, which assures dynamic prediction on the underlying topology network. Combined with P2P distributed shared technology calculation model, taking advantage of idle node storage and computing power, this idea makes them work together to improve router discovery process, and to improve MANET routing efficiency. At the same time, interfaces for publishing and sharing of information resources are reserved for the system application layer, which increases upper-layer application system development efficiency.

The design of LDSR architecture (Fig. 1 below) is a main-loop domain spatial topological overlay (Primary and Secondary ring zone topology Overlay, abbreviated as PSRZTO) and overlay based on DHT shared resource (DHT share resource overlay, abbreviated as DHTSRO). The unified entity of these two types of different hierarchical structure covering layer (overlay) shall be suitable to be applied to large-scale MANET environment and can provide information services for application layer such as file resources discovery, information management, files resources transferring and communications security.

3 LDSR Algorithm Design

The routing algorithms designed in LDSR are a series of algorithms based on MANET network layer. They used hash routing algorithm based on DHT, modifying Chord algorithm on the basis of DSR algorithm and running DHT based structuralized P2P algorithm on Primary-secondary Ring Zone. Router sharing and information communication are effectively achieved between
Fig. 1: LDSR tiered architecture

mobile nodes.

3.1 Node nomenclature

LDSR’s node nomenclature is similar to Chord algorithm. Applying Consistent Hashing algorithm, IDs of every node (such as IP address, URL etc.) is mapped as a binary series of M bits (NID Node Identifier). Each NID is uniquely assigned to a specific node. For items that stores data (such as router resource name, secondary ring member name etc), Hashing algorithm map them to another set of binary series of length M bits (KID key identifier).

3.2 Routing information of node

LDSR routing table on primary-secondary ring zone made a lot of improvements on finger table in Chord protocol. Node naming algorithm and the structure of the overlay are both quite different. The list below defines several concepts related to LDSR routing table in M-bit naming space:

- **Node attribute**: Nodes in Hashing ring zone are categorized into two groups: Ring Header (RH) and Ring Member (RM).

- **Node identification**: Nodes set up in the layered topology overlay is performed by mapping the nodes in Hashing ring zone. RH node identification is mapped as \((RH_i, <RM_1, RM_2, RM_3, ... RM_s>)\), which represents RH node and RM list. Ring member node identification is identified as \((RM_j, RH_i)\), which means the ring member and the beginning member of the ring it belongs to. (P: maximum number of nodes in the primary ring, S: maximum number of nodes in the secondary ring, \(2 \leq i \leq P, 2 \leq j \leq S\)).

- **Predecessor**: The first node one met tracing counter clock wise on a Hashing ring zone.
• Successor: The first node one met tracing clock wise on a Hashing ring zone. LRTEntry [K].start: the starting point of Hashing ring zone covered by the Kth router table item.

\[
LRPTEntry[K].start = (NID + 2^{k-1})mod2^M, 1 \leq K \leq M
\] (1)

• Next Hop Ring Interval (NRI): the size of the range covered by the Kth item on router table.

\[
NRI[K] = (LRTEntry[K].start, LRTEntry[K+1].start), 1 \leq K \leq M
\] (2)

• Next Hop Identifier (NHID): NID of the first active node G tracing clock wise in NRI

\[
LRTEntry[K].start \rightarrow NID(G), 1 \leq K \leq M
\] (3)

• Next Hop Source Route (NHSR): The source router to Next Hop G. Assume S1 is the origin node? NHSR satisfy:

\[
NHST =< S_1, S_2, S_3, ..., G >, 1 \leq K \leq M
\] (4)

LDSR routing table has basic content including: PRTEntry [K]. start, NHID, NHSR. K is the index number in routing table.

3.3 Domain space topology construction algorithm

LDSR is a data communication driven protocol which layer by layer builds primary-secondary ring zone network topology. This step by step building process avoids the large cost at SPDSR [8] network initialization due to construction of Hashing ring zone over the entire network. Router protocol can be quickly compressed to improve the expandability of network. At same time, when churning of mobile nodes is increasing, maintenance of Hash ring is normally restricted within secondary ring, which avoids the cost of maintenance over the entire network. Therefore, the small to medium size MANET has strong stability which is a necessary feature for large scale MANET environment. Need-based ring zone assignment mechanism constructs need-based primary-secondary ring zone guided by the need of sending data from each node and gather nodes within a radius of K hops to form a secondary ring zone from which the primary ring zone is composed by the first member of each secondary ring. In this way, the primary-secondary ring zone network topology structure is constructed.

3.4 Router resource publication and sharing algorithm

There are router resource publication and sharing algorithm for secondary ring as well as primary ring.

3.4.1 Secondary ring router resource publication and sharing algorithm

This algorithm publishes and shares the router resource from every DSR router according to some predefined rules. Each node step by step will achieve the shortest route to another node.
Secondary ring router publication is activated by source node when secondary ring is formed, when a new member is added or when router is not achievable. Router resource \( <K, V> \) is chosen according to the rule: router resource publication node along router’s discovery route choose multiple-hop routers within the radius of secondary ring. \( K \) represents key word for searching router, \( V \) means realistic route. For example: from node A to node F, the route is “A-C-H-D-F”, \( <K, V> \) pair is represented as \( <AF, ACHDF> \). Objective of the design of this algorithm include:

1. Intelligentize nodes to make them collaborate. The algorithm combines distributive sharing and collaboration in P2P computation mode to change the situation in tradition MANET where mobile nodes are relatively independent. The algorithm keeps adding to Hashing ring zone nodes that are physically close together step by step. Mobile nodes are actively involved in secondary ring router resource publication and sharing process when network is idle, as a result, the efficiency of router will increase as the number of nodes increases.

2. Reduce stretch value to make sure P2P logic topology is consistent with MANET physical network. This article uses the secondary router resource publication and sharing algorithm to make sure the shortest router is used when nodes are communicating with each other, therefore, stretch=1. In this way, the secondary ring zone and MANET physical network are consistent.

### 3.4.2 Primary ring router resource publication and sharing algorithm

This algorithm publishes and shares the member lists that belong to 1st member of each ring, so that all 1st members are able to search for any node in the primary-secondary ring zone. Router resource publication and sharing on primary ring is performed by each ring member node when primary ring structure is finished and when new member of primary ring is added. Primary router resource \( <K, V> \) is defined in the following way: \( K \) is the keyword of secondary ring member that support the search; \( V \) is the 1st member of the secondary ring. For example, node A belongs to a secondary ring whose 1st member is F, \( <K, V> \) pair is represented as \( <A, F> \). Router resource publication node gains the primary ring right of control, then takes \( <K, V> \) pair form the publication queue, and then publish this secondary node to the corresponding destination according to Chord keyword algorithm, at last, it releases the primary ring right of control.

### 3.5 Router search algorithm

This algorithm provides router search between nodes and ensures that upper level business data can be sent in time. When searching for router, first check in local router cache for destination router information, if yes and the router is still valid, search is finished (In the case of router expiration, delete expired router); else keep searching in the order of “source secondary ring-primary ring-destination secondary ring”. If destination is not achievable, activate DSR router to finish search.

At the same time, after the search is finished, the shortest route information is stored into local cache. As time progresses, the node will have more and more the shortest route information, which speeds up the router inquiry speed. This method moves router information back and forth from primary ring to secondary ring can dynamically balance the advantage of Proactive Routing
Strategy and Reactive Routing Strategy. When the network is stable, because of the increase amount of router information stored in local cache, more router information can be retrieved directly, which corresponds to Proactive Routing. When network is shaking and unstable, there would be more invalid router information cached locally, and most router will be retrieved from dynamically maintained primary-secondary ring zone, which reflects Reactive Routing Strategy.

3.6 Router maintenance algorithm

Router maintenance algorithm has similar way of adding and deleting nodes as in Chord algorithm, so it is not discussed here. When 1st ring member is deleted, the subsequent node is automatically promoted to be the new 1st member. Information related to new 1st member is also updated.

4 LDSR Experiment Results

Fundamental performance of router protocol is evaluated by Average Path Length (APL), Routing Overhead (RO), Packet Deliver Ratio (PDR) and so on. In this section, LDSR will be analyzed using the three factors listed above, comparing with a representative of need-based router protocol: DSR and standard protocol that support large scale MANET: ZRP [9]. Simulation results are discussed to indicate potential development on LDSR performance in large scale MANET environment.

This article uses NS2 as router protocol development platform based on which analysis of router algorithm performance is conducted. The simulation environment setup uses MANET router protocol simulation environment in CMU Monarch group and simulation testing data of Wireless System Lab in Stanford as reference [10]. Simulation environment setup is described in detail as below:

(1) Simulation environment: nodes are simulated 500s in 2000m 2000m space Every node interface has the following physical parameters: Isotropic antenna, height = 1.5m, transmission and receiving gain = 1dB, wireless bandwidth = 2Mb/s, two-ray ground reflecting model, Transmission power = 17.6 mW wireless nodes have broadcast radius of 110m.

(2) Mobile mode: Random Waypoint Mobility Model, RWP [32]. Pause time, PT = 50s, moving speed = 5m/s.

(3) Working mode: to better monitoring the effects of parameters on router protocol performance, load is randomly chosen from 20, 40, 80, 120, 160 and 200. Every node transmits data in CBR type groups. Every CBR stream has 5 sec/group of 128 bytes.

(4) MAC:802.11 Distributed Coordination Function, DCF.

4.1 Average path length, APL

From Fig. 2, LDSR always has APL of smaller than 10, while DSR and ZRP linearly increases.
4.2 Routing overhead, RO

Fig. 3 shows that under small scale network environment, LDSR router resource publication algorithm creates extra cost. RO of LDSR is slightly higher than DSR and ZRP. However, as the scale of network increase, the advantage of LDSR based on P2P distributive search is more obviously presented. The control cost and maintenance cost are kept at a low level. The overall RO is smaller than DSR and ZRP.

4.3 Average end-to-end delay, AED

Fig. 4 shows that DSR has the highest AED due to the broadcast router search and inquiry algorithm. ZRP and LDSR have very close AED when number of nodes stay within 200. But as node number increases, ZRP router hop number increases, which leads to failure rate of router search. LDSR can take advantage of the calculation and storage resource on idle nodes to speed up router search speed and sharing process. The more nodes there are, the more available routers there could be, which ensures a faster arrival of data package. The AED of LDSR stays at a low level.
4.4 Packet deliver ratio, PDR

Fig. 5 shows the failure rate of connection between nodes increases and PDR decreases as node number increase. DSR shows the most significant drop, but LDSR’s primary-secondary ring zone structure can take advantage of the vicinity neighbor mobile nodes and thus keeps PDR at a higher level.

5 Summary

This article proposes a router protocol LDSR that is applied to large scale MANET on the basis of structured P2P computing. The protocol divides network into different levels based on real network topology and P2P distributive sharing strategy, which allows router information to be published and shared between layers. This method effectively solves the problem of detour and increases the MANET router performance. LDSR protocol has already been granted a patent from State Intellectual Property Office.

References