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SN-Pass Scheme for Flow Control and Incentive Engineering in Non-Cooperative MANETs

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Abstract: A mobile ad hoc network (MANET) is formed by a group of mobile nodes connected by wire-less links. The nodes can talk to each other by direct peer-to-peer wireless communication when they are close to each other. When the sender and receiver are far away, their packets can be forwarded by the intermediate nodes along a multi-hop path. As an emerging networking technique, a MANET is envisioned to become a stand-alone network for a group of mobile users, or as a stub-network to connect to the Internet. In this paper, we focus on the flow control problem in this network. Depending on whether the routers agree to forward packets for each other, different flow control schemes are proposed for both cooperative and non-cooperative MANET environments. Traditionally, flow control has been studied in a cooperative network environment. But co-operative behavior is not a realistic assumption in a public MANET formed by a random group of strangers. Users in this network are likely to behave selfishly, by refusing to forward other users' packets. Under this non-cooperative environment, flow control and incentive engineering are two problems closely related to each other. A flow control solution would be meaningless if the inter-mediate routers do not agree to carry the traffic for others. However, existing work in incentive engineering provides only stand-alone solutions and fails to recognize its close relation with flow control. Hence, we propose a scheme called which SN-Pass, is a joint solution for flow control and incentive engineering in MANETs. SN-Pass adopts the "pay for service" model of cooperation and utilizes an auction mechanism at each router to fairly allocate bandwidth resources. Therefore, SN-Pass provides an innovative and graceful solution for the flow control and incentive engineering problems in a non-cooperative MANET environment.

Key words: Manet · TCP-ID · Micro-payment approach · AIMD

INTRODUCTION

So far the flow control schemes we have studied (TCP, equation-based and EXACT) all assume a cooperative network environment where each user agrees to forward packets for others in the network. Such cooperative behavior does exist in military and emergency missions; however, it is not a realistic assumption in a public MANET formed by a random group of strangers. Mobile users with a small computing device usually face limited resources, such as battery, CPU and memory. In order to save these resources, they are likely to behave selfishly, for example, by refusing to forward other users' packets and hence paralyze the whole network [1, 2]. Setting up bi-lateral cooperation agreements between the MANET users is not practical due to its large administrative costs and lack of scalability. The core of this problem lies in the fact that a public MANET is formed by a group of self-interest autonomous entities. Although the users are selfish, we can assume that they are rational. Therefore, a promising way to foster cooperation is via certain incentive mechanisms [3]. This is the so-called incentive engineering problem. The issue of cooperation has received a lot of attention in the context of mobile multi-hop ad-hoc wireless LAN networks [4, 5]. In an ad-hoc network, participating nodes may be self-interested, they may selfishly turn down the forwarding traffic flow for the other nodes and only transmit its own generated traffic for the reason of saving energy etc. But if every node performs in this manner, no traffic can traverse multiple hops and network throughput will degrade unacceptably [6]. Therefore, a

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good utilization of the scarce wireless resources in the whole ad-hoc network depends on the cooperation among participating parties. Stimulating the cooperation, thus, is a crucial issue in non-cooperative mobile ad-hoc networks.

In a public mobile ad hoc network (MANET), users may be selfish and refuse to forward packets for other users. Therefore, an incentive mechanism must be in place. In this paper, we adopt the pay for service model of cooperation and propose an auction-based incentive scheme (called SN-Pass) to enable cooperative packet forwarding behavior in MANET. Each flow pays the market price of packet forwarding service to the intermediate routers [7].

In human society, monetary rewards are usually given for providing services. The same principle should also apply in a MANET, considering the fact that mobile devices are ultimately owned and controlled by human users [8]. To some extent, forwarding packets in a public MANET can be considered as a user's service to others. In this paper, we study the flow control problem in a non-cooperative network environment [9, 10].

Traditionally, flow control and incentive engineering are two separate problems. For example, over the Internet, flow control is usually taken care of by TCP or some rate-based schemes. Packet forwarding is assumed to be cooperative by Internet Service Provider's (ISP's) agreements to carry traffic for each other. However, over a public MANET, flow control must consider the willingness of the intermediate routers to forward packets. A flow control scheme without incentive engineering is meaningless. Therefore, we investigate how incentive engineering can be combined with flow control in our study. To this end, we propose a *joint* flow control and incentive engineering scheme called SN-Pass (Secured Network comPatible Auction based Service Scheme), as our solution in a non-cooperative MANET.

Overview of Flow Control: Like in wire line networks, end-hosts in MANETs must face the non-trivial problem of deciding how fast they can send packets to a destination over the network. This is the flow control problem in networking research. Flow control has two general goals: efficiency and fairness. Efficiency refers to the property that the aggregated traffic at the bottleneck router should match the available. In some literature, the term "flow control" is reserved for speed matching between a pair of sender and receiver and "congestion control" is used for regulating the speed of sending packets to avoid congestion. Their meanings should be clear from the context. bandwidth of the outgoing links [11]. If traffic is too slow, the links will become idle and waste some valuable bandwidth; if traffic is too fast, it will cause packet dropping and long queuing delays. Fairness refers to the property that each competing flow should get its "fair" share of the available bandwidth. There are many fairness criteria. For example, max-min fairness assumes that each flow has equal rights to access the resource and hence divides the available bandwidth equally for the competing flows. Some other fairness criteria may take each user's valuation (or satisfaction) for the resource into account and allocate the resource accordingly [12]. In a MANET, flow control is especially important because a MANET's limited bandwidth often cannot meet the full demand of many applications. At the same time, flow control faces many new challenges in a MANET because it is a much more dynamic networking environment than wireline networks [13]. Flow control in a cooperative network environment, i.e., each router agrees to forward packets for others. This is the approach taken by the Internet, as the routers are owned by a single organization or a set of ISPs with mutual agreements to carry each other's traffic. In a public MANET, this assumption is not true because the network is formed by a random group of strangers in a spontaneous fashion [14]. Flow control problem in this environment as non-cooperative flow control. In order to enforce non-cooperative flow control, an incentive engineering component must be in place.

Cooperative Flow Control: In a cooperative network environment, flow control can be broadly categorized into two types: implicit and explicit, depending on how the network congestion state is measured.

Implicit Flow Control: In implicit flow control, the network congestion state is measured at the end-hosts by their performance measurements, such as packet loss and delay. The flow control functions are implemented at the end-hosts. This greatly simplifies the design of the routers (i.e. "dumb" routers). Over the Internet, two prominent examples of implicit flow control are TCP's AIMD (Additive Increase Multiplicative Decrease) and the TCP equation-based approach. AIMD views the network as a black-box and infers congestion by packet loss events. The equation-based approach is based on a TCP throughput equation that captures the steady-state TCP throughput under certain loss rate and packet round-trip time conditions [15].

Another prominent implicit flow control scheme in the Internet is the TCP equation-based approach. It is driven by the need of multimedia streaming over the network, which requires smooth rate adjustments. At the same time, it should be able to obtain approximately the same throughput with a competing TCP flow under the same network conditions, i.e., being TCP-friendly. Over the Internet, the equation-based flow control approach has been shown to achieve reasonable fairness with competing TCP flows under a wide range of traffic conditions. The protocol that implements the TCP-equation based approach is TFRC (TCP Friendly Rate Control). With the emerging need of multimedia streaming, equation-based congestion control is likely to find its way into MANETs as well, for example, by reusing the same software that has been developed for the Internet. However, the behavior of equation-based congestion control is very much unknown in MANETs. Under this environment, it is unclear whether TFRC will be able to compete fairly with TCP and if not, what are the factors that contribute to such behavior. TFRC is able to maintain smooth rate changes, its throughput is often "beaten" down by competing TCP flows to a certain degree, especially under heavy background traffic and dynamic topology conditions. Fundamental difficulties of equation-based flow control in MANET, such as loss rate estimation of the network. Therefore, although equation- based flow control is a successful proposal for the Internet, it has serious limitations when applying to the MANET domain.

Explicit Flow Control: The deficiencies found in TCP and equation-based congestion control in MANETs have led us to consider the alternative type of flow control scheme, i.e., explicit flow control. Explicit flow control relies on the network elements (i.e., routers) to measure the network congestion state and to inform the end-hosts of such state by explicit control messages. Essentially, this is a router-assisted flow control mechanism. Since routers are the actual places where congestion occurs, they are in a much better position to detect and react to such conditions. Therefore, explicit flow control is enerally more responsive and accurate than its implicit counterparts.

Existing Incentive mechanisms in MANET: Before going into details of our solution, we survey the existing incentive mechanisms for enforcing packet forwarding in MANETs and discuss their respective strengths and weaknesses. Two general approaches can be found in the literature: 1) game theory approach; and 2) micro-payment approach.

Game Theory Approach: In this approach, a packet forwarding game is designed and played by all the nodes in the network. In early studies, each node is ranked with a reputation based on its packet forwarding behavior observed by other nodes in the same neighborhood. A node's reputation can be learned by other nodes farther away from the neighborhood, similar to a group of "friends" sharing information with each other. A node with bad reputation is then refused service by other nodes and hence isolated from the network. If the cost of a bad reputation is prohibitively high, all the nodes will choose to cooperate. However, in these studies, the cost of a bad reputation is not precisely given.

This situation is not as simple as it sounds, because a node may *not* need some other node's help to forward its traffic. Therefore, the game analysis in this strand of study tends to be over-simplified and incomplete. The concept of a dependency graph is introduced to represent the forwarding dependency of a node to another, a symmetric dependency model is assumed. When there is a mutual dependency relationship between two nodes, the packet forwarding game can be modelled as a repeated Prisoner's Dilemma game, where a simple "tick-for-tack" strategy can be implemented to encourage mutual cooperation. The dependency requirement means that, a node's cooperative behavior can be enforced in the packet forwarding game, only when its non-cooperative behavior can be "punished" by the nodes that it has previously refused to serve for. If there is no such mutual dependency, cooperation cannot take place. For example, in a MANET stub network where a node is closer to the base station than all the other nodes, mutual forwarding dependency does not exist. Therefore, although the game theory approach is simple to implement, it has serious limitations in a MANET. To facilitate payments between the nodes, we design a simple credit-based payment scheme. Our solution relies on a trusted third party(i.e., bank) to issue a credit certificate to each node in good financial standing and let the nodes use their certificates to "purchase" services, similar to using a credit card. The evidences of packet forwarding are collected by each router and later sent to the bank in bulk for processing.

Micro-payment Approach: Micro payment approach adopts the "pay for service" model of cooperation: routers are fairly compensated for their forwarding services. It requires no assumption about the forwarding dependency and hence is a more general solution.

One challenge of making a payment in a MANET is that, since the payment is digital, security mechanisms have to be in place to prevent currency forgery and fraudulent claiming of funds. Research in this area is to provide a secure payment system for MANET nodes to exchange funds. In summary, a secure payment system solves the problem of how to pay for packet forwarding service in a MANET. An equally important question is how much to pay for the service, which is the focus of SN-Pass. But as an extension, we have also designed a simple payment scheme to facilitate exchanging funds between the nodes.

Design Principles

"Pay for Service" Model of Cooperation: We adopt the "pay for service" model of cooperation in SN-Pass, where the sender must provide monetary rewards to the intermediate routers for their packet forwarding service. We adopt this approach because it is a general model of cooperation applicable to any packet forwarding scenarios in a MANET.

To facilitate payments between the nodes, we design a simple credit-based payment scheme. Our solution relies on a trusted third party (i.e. a bank) to issue a credit certificate to each node in good financial standing and let the nodes use their certificates to "purchase" services, similar to using a credit card. The evidences of packet forwarding are collected by each router and later sent to the bank in bulk for processing.

Auction-Based Resource Allocation: In SN-Pass, each router is owned by an individual user who acts for his or her own benefit. To determine the resource allocation and pricing, we adopt the *auction* mechanism from economics. Each router constitutes an "auction market" (or "smart market"), where an auction process runs continuously to determine who should obtain how much of the bandwidth and at what price. Here auction is used not only as a resource allocation mechanism, but also as a pricing mechanism. The bidders are the traffic *flows* currently passing that router. Each flow carries a bid indicating its willingness to pay for the forwarding service. Based on these bids, the router runs a "generalized auction" to determine the bandwidth allocation for the flows.

Explicit Rate-based Flow Control: As mentioned earlier, SN-Pass is a joint solution of flow control and incentive engineering in a MANET. From the flow control perspective, SN-Pass is an explicit flow control scheme, a router in SN-Pass allocates bandwidth explicitly for the flows currently passing the router. The rate information is carried with each data packet to the receiver as part of a signaling protocol and subsequently returned to the sender as feedbacks.

In SN-Pass, router's bandwidth is auctioned off to the competing flows (i.e. bidders) with a market price determined by the bids and the auction rule.

The SN-Pass Scheme

Preliminaries: In economics, auction is a simple and well-known mechanism in allocating limited resources to a group of competing bidders. There are many auction formats. Among them, the sea bid second-price Vickrey auction is the most well-studied auction format, due to its many desirable properties. Depending on whether there is only a single unit of good, or there are multiple units of goods to be allocated, Vickrey auction can be classified into two types: basic Vickrey auction and generalized Vickrey auction. Although basic Vickrey auction is a special case of the generalized Vickrey auction, we give them separate introductions below for ease of understanding.

Basic Vickrey Auction: In a basic Vickrey auction, there is only one unit of indivisible good. Bidders submit their bids to the auctioneer; after receiving all the bids, the auctioneer awards the good to the highest bidder at the price of the second highest bid (which is the highest losing bid). Take a simple example: there are 5 bidders bidding for a book and their bids are 10, 9, 5, 3 and 2 (units of currency). The result of the auction awards the book to the highest bidder (who bids 10), but the bidder only pays 9 (which is the second-highest bid).

In this auction, the optimal strategy for each bidder is to bid her *true valuation* for the good,which is the valuation (or satisfaction) of the user if she wins the good 2.

Generalized Vickrey Auction: When there are multiple units of the *same* goods and each user may request more than one unit, the auction becomes the generalized Vickrey auction. In a generalized Vickrey auction, the goods are awarded to the highest bidders until exhausted and each winning bidder pays a price of the "opportunity cost" for winning the goods, which is the cost to the losing bidders *if* the winning bidder would *not* have participated in the auction.

Opportunity cost is better understood with an example. Let's assume that there are two bidders bidding for three copies of the same book. The first bidder values winning the first copy of the book at 10, the second copy at 8 and the third copy at 5. The second bidder's valuation for the first copy is 9, for the second copy is 7 and for the third copy is 6. That is, the valuations to obtain the book by the two bidders are: (10, 8, 5) and (9, 7, 6) respectively. In this auction, the goods are the three copies of the book. According to the auction rule, they are awarded to the *highest* bids of the two bidders. That is, the first bidder gets two copies of the book (valued at 10 and 8). The second bidder gets one copy (valued at 9). For the first bidder, the price to pay for the two copies of the book are 7 and 6, because the first bidder did not participate in the auction, the second bidder would have obtained the two copies valued at 7 and 6. In other words, the first bidder pays the "opportunity cost" of the second bidder for losing the two copies of the book. Likewise, the second bidder pays 5 for getting one copy, which is the "opportunity cost" of the first bidder for losing the copy. Clearly, the basic Vickrey auction is a special case of the generalized Vickrey auction where each bidder can only bid for one unit of good and there is only one unit of good available.

Seller's Reserve Price: In the basic and generalized Vickrey auctions, the seller has the option to declare a *reserve price* for selling the goods. This is often used as a preventive mechanism when the auction market is not competitive and hence the bids are too low. Using a reserve price, the seller will withhold the goods if the bids are too low. Take the generalized Vickrey auction example where two bidders bid for three copies of the same book at: (10, 8, 5) and (9, 7, 6). If the seller's reserve price is set at 8.5, only two copies of the book will be sold, because only two bids (i.e. 10 and 9) are higher than the reserve price. The seller will withhold the third copy of the book because the next highest bid (i.e. 8) is too low. In a competitive auction market, reserve pricing is usually not needed, because the market demand will properly set the auction price. However, it can be used as a safeguard mechanism to protect the seller from selling the goods at a price lower than the cost

CONCLUSION

We propose a joint incentive engineering and flow control scheme, called SN-Pass, to enable packet forwarding service in a public MANET. Our scheme is based on the "pay for service" model of cooperation and relies on the multiunit generalized Vickrey auction as the resource allocation mechanism. We prove that under the SN-Pass scheme, it is incentive compatible for the users to bid their true utilities and further we prove that packet forwarding always leads to higher social welfare for the whole network.

REFERENCES

1. Maruti Gupta and Suresh Singh, 2007. Dynamic Ethernet link shutdown for power conservation on Ethernet links, IEEE ICC'07, Glasgow, Scotland, pp: 24-28.
2. Harkirat Singh and Suresh Singh, 2005. Smart-Aloha for multihop wireless networks, J. Mobile Networks (MONET) Special Issue on "WLAN Optimization at the MAC and Network Levels", 10: 651-662.
3. Yarvis, M., N. Kushalnagar, H. Singh, A. Rangarajan, Y. Liu and S. Singh, 2005. Exploiting Heterogeneity in Sensor Networks, IEEE INFOCOM 2005, Miami, FL, pp: 13-17.
4. Mike Woo and Suresh Singh, 2001. Scalable routing protocol for ad hoc networks, ACM Wireless Networks, 7(5): 513-529.
5. Jian Liu and Suresh Singh, 2001. ATCP: TCP for Mobile Ad Hoc Networks, IEEE J-SAC.
6. Sandeep Agrawal and Suresh Singh, 2001. An Experimental Study of TCP's Energy Consumption over a Wireless Link, 4th European Personal Mobile Communications Conference, Feb 20-22, Vienna, Austria.
7. Hu Zhou and Suresh Singh, 2000. Time-Space Multicast for Integrated Sensor/Battlesite Networks, Proc. IEEE MILCOM 2000, Los Angles, CA, pp: 22-25.
8. Hu Zhou and Suresh Singh, 2000. Content-based Multicast for Mobile Ad Hoc Networks, Proc. ACM MOBIHOC 2000, Boston MA.
9. Wenli Chen, Nitin Jain and Suresh Singh, 1999. ANMP: Ad hoc network Network Management Protocol, IEEE J-SAC.

10. Thooyamani, K.P., V. Khanaa and R. Udayakumar, 2013. Application of Soft Computing Techniques in weather forecasting : Ann Approach, Middle-East Journal of Scientific Research, ISSN: 1990-9233, 15(12): 1845-1850.
11. Thooyamani, K.P., V. Khanaa and R. Udayakumar, 2013. Improving Web Information gathering for personalised ontology in user profiles, Middle-East Journal of Scientific Research, ISSN:1990-9233, 15(12): 1675-1679.
12. Saravanan, T., V. Srinivasan and R. Udayakumar, 2013. A Approach for Visualization of Atherosclerosis in Coronary Artery, Middle-East Journal of Scientific Research, ISSN: 1990-9233, 18(12): 1713-1717.
13. Saravanan, T., G. Saritha and R. Udayakumar, 2013. A Robust H-Infinity Two Degree of Freedom Control for Electro Magnetic Suspension System, Middle-East Journal of Scientific Research, ISSN:1990-9233, 18(12): 1827-1831.
14. Udayakumar, R., V. Khanna, T. Saravanan and G. saritha, 2013. Retinal Image Analysis Using Curvelet Transform and Multistructure Elements Morphology by Reconstruction, Middle-East Journal of Scientific Research, ISSN: 1990-9233, 16(12): 1798-1800.
15. Udayakumar, R., V. Khanna, T. Saravanan and G. saritha, 2013. Cross Layer Optimization For Wireless Network (Wimax), Middle-East Journal of Scientific Research, ISSN: 1990-9233, 16(12): 1786-1789.