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Analyzing Credit Based Incentive Mechanisms in Delay Tolerant Network: A Survey.

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A B S T R A C T

A Delay tolerant network (DTN) is an approach to computer network architecture that seeks to address the technical issues in the heterogeneous networks that may lack continuous network connectivity. DTN is specially designed to operate effectively over extreme distance such as those encountered in space communication or an inter-planetary scale. Store-carry-and-forward mechanism is used in DTN to route the bundles from source to destination. In-transit bundles are routed to the destination with an assumption that the nodes are willing to help other nodes for packet forwarding. In real time applications nodes in DTN may exists with selfish behavior. Hence, our assumption about DTN nodes that they always co-operate in bundle forwarding in all applications is not realistic. To address the selfishness problem in DTN, researchers proposed different credit based incentive mechanisms and suggest that some incentive should be provided to the selfish DTN nodes so that they can participate in the packet forwarding. In this paper, we studied and analyze the various credit based incentives schemes and stated a comparative study. There are some open research issues in DTN which are stated in the conclusion.

Index Terms: DTN, Store-Carry-And-Forward, Selfishness, Credit Based Incentive Protocols

I. INTRODUCTION

DTN is a network of regional networks. It resides on top of regional networks and internet is also part of it [1]. DTN support interoperability of the networks which covers it by including long delays between and within regional networks. There exists many networks including internet also may not have assumptions which are associated with DTN. Characteristic of DTN are explained below [1]:

Intermittent Connectivity: In a situation that, if there is no end to end connectivity present then a network may divide into one or many parts called Network Partitioning and in such situation TCP/IP protocols does not work. Other protocols than TCP/IP should required.

Long or Variable Delay: Apart from intermittent connectivity, variable queuing delays at nodes and long propagation delays between nodes contribute to end to end delays that may beat various applications and Internet protocols which depends on quick return of acknowledgements or data.

Asymmetric Data Rates: Users with cable TV which uses Internet supports moderate asymmetric nature of full duplex links which has bi-directional data rate, if asymmetric nature is large, they can beat the conversational protocols.

High Error Rates: As the links are highly asymmetric bit errors on links must be identified and must

have to correct (which requires extra parity bits and more processing power of CPU) or retransmission of the sent packet. There are some retransmissions of entire packets are needed including hop to hop other than end to end retransmission. The DakNet project of India is a typical example of DTN [2].

A. Store-carry-and-forward Message Switching Technique in DTN

DTN removes the problems including high error rates, asymmetric data rates, intermittent connectivity and variable delays etc. using store-carry-and-forward message switching mechanism. At ancient times this old method is used in postal systems. Entire messages (application program user data block) or fragments of application data are forwarded from a storage place on one site to other node which has storage capacity, followed by a path which reaches to the destination. e.g. An e-mail & voice-mail system uses store-carry-and- forward mechanism. Though these systems are not only include one way cover but also has star communication. There is a central storage device is independently contacted by the source and destination.

There are many storage places like memory chips which can store data for a short period of time and hard disks which can hold messages for a long time called persistent storage. Routers in the network store the packets or queued the packets for a very short time may be a milliseconds use memory chips. When they are looking and waiting for their next router routing table look-up and search for outgoing router port. Routers which are used in the DTN need persistent storage for their queuing of data packets for a long time for the reasons which explained below:

For a long time link may not be available to the next node for communication. Nodes may have different sending and receiving data rates. Message retransmission is needed which is transmitted before when any error occurs at an intermediate node which is towards the destination or intermediate node decided to reject the forwarded packets. Single transfer moving of entire packets or the fragments of packet the message switching technique is used which provides knowledge of the size of messages by the nodes of the network. Therefore, intermediate storage space and retransmission bandwidth is very essential in such type of networks. Store-carry-and-forward mechanism is shown in Figure 1.1.

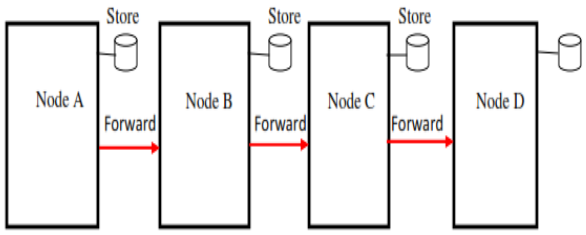

Figure 1. Store-carry-and-forward mechanism

B. DTN Protocol Stack

The unit of information exchange in a DTN is a bundle. Bundle layer is associated with every DTN node. In a typical network, using a common set of network layers (such as TCP and IP). In a DTN, the bundle layer is placed below the application layer and hides the actual network or region specific communication layers, as depicted in Figure 1.2. A network-specific convergence layer is used underneath the bundle layer as to interface with each different network layer protocol used. The Bundle Protocol (BP) is defined in RFC 5050 [3] and implements a bundle layer in the DTN architecture defined

in RFC 4838 [4]. The Bundle Protocol provides six classes of service (CoS) for a bundle, namely: Custody Transfer, Return Receipt, Custody-Transfer Notification, Bundle-Forwarding Notification, Priority of Delivery (bulk, normal, expedited), and Authentication. In DTN, forwarding nodes (routers and gateways) can be authenticated. The unique characteristic of the bundle layer is the support for in transit storage. Bundles received from a sender can be stored in an intermediate node for an excessive amount of time (minutes, hours, or even days). These store operations are performed by the network stack, at the bundle layer, transparently to the application. The in-transit storage is the means to overcome the delays and disruptions induced while a bundle moves hop-by-hop to its final destination to avoid costly end-to-end retransmissions due to errors or timeout; and to allow exchange of information between two nodes that share no end-to-end communication path at any given time moment. The bundle protocol defines a custody operation which allows an intermediate node to handle bundle delivery to final destination on behalf of a more distant sender.

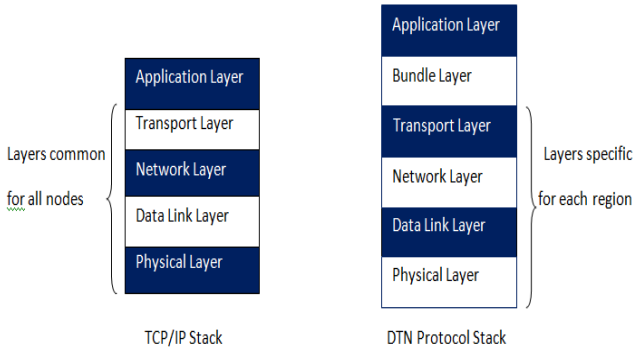

Figure 2: DTN specific protocol stack

In this paper, we analyze the credit based incentive mechanisms and selfish behavior of the nodes. The remaining paper is organized as follows. In Section II we briefly introduce the selfish behaviors of DTN. Section III explains about the different credit based incentive mechanisms of DTN. Section IV gives the comparative study of existing credit based incentive protocols and Section V discusses conclusion and further research issues.

II. SELFISH BEHAVIOR OF DTN NODES

In a typical DTN deployment, people from remote cities use their battery operated hand held devices. These devices are easy to carry but they are energy constraint. There are many nodes in the DTN which are selfish. Due to the limited resources like battery power and buffer space, forced the node not to cooperate with others. The three main issues of research interests in the aspect of cooperative techniques [5]:

1. Seek for the non-cooperative nodes.
2. The affections cooperation put on the performance of the whole network.
3. Design protocols for the nodes' cooperation.

A lot of existing forwarding algorithms are based on the assumption that all the nodes are willing to forward messages for others. But in the real applications of DTN, such as human social networks and Vehicular Ad Hoc Networks, this is not the case. In order to maximize their own rewards, the nodes may not be willing to forward messages under the constraint of energy. This rational behavior is called selfish behavior in DTN. Since, selfish nodes are present in DTN it will damage the routing scheme. Then how to stimulate the selfish nodes to take part in the relay of messages has become an interesting and essential issue which has attracted many researchers focusing on this problem. The method to solve this problem is often called incentive mechanism.

III. CREDIT BASED INCENTIVE MECHANISMS

As we discussed in Section II, how to stimulate the nodes joining in the relaying of messages has become a hot topic during these years. And in this section, we will make a detailed analysis of the existing credit based incentive mechanisms.

A. SMART Mechanism

Secure multilayer credit based incentive (SMART) scheme proposed by Haojin Zhu et al. [6]. SMART enforces the DTN nodes for bundle forwarding towards the destination node. Co-operation between the DTN nodes for bundle forwarding is the ultimate aim of SMART. SMART resists various attacks in DTN and does not require any tamper proof hardware.

The concept of Naive multilayer coin is the base of SMART. When a node sends a messages, the node will lose credit and other helping nodes gets credit for their co-operation. Source node which sends a bundle first generates the base layer of a layered coin and then sends it together with the original bundles to a certain number of intermediate nodes. New endorsed layer is generated by each intermediate node based on the previous layered coin. Layered coins are used to track successful data-forwarding process. Periodically each intermediate node submits its collected layered coins to the virtual bank (VB), which can calculate credits for each intermediate node and make a charge on the bundle senders. Selfish nodes can launch different attacks, since helping intermediate nodes only gets the rewards.

B. Pi Mechanism

Rongxing Lu et al. [7] propose a practical incentive protocol (Pi), address the selfishness problem in DTN. When source node sends a bundle to the destination through intermediate nodes source attaches some incentive to the bundle which is attractive and fair. Fair incentive strategy is used to stimulate the DTN nodes for bundle forwarding. Better packet delivery is achieved in this mechanism. Selfish DTN nodes can initiates various attacks. Pi protocol can resist to attacks which are listed below:

1. Layer adding attack
2. Layer removing attack
3. Free ride attack

There exists a trusted authority (TA) in the proposed Pi protocol. TA does not participated in bundle forwarding process. TA performs trusted fair credit and reputation clearance for DTN nodes. In the initialization phase, each DTN node when joining the DTN, should register itself to the TA. Nodes which are registering to TA should obtain:

1. Personal credit account (PCA)
2. Personal reputation account (PRA)

TA performs credit and reputation clearance when any DTN node reported to it, when fast connection is available with TA. For example, in the vehicular DTN, a vehicle can communicate with TA for clearance when it makes contact with some Road Side Units (RSUs). For successful packet delivery to destination node, intermediate helping nodes gets credit and reputation value. However, for unsuccessful packet delivery to destination node, intermediate helping nodes still gets reputation value.

C. MobiCent Mechanism

MobiCent, a credit based incentive system for DTN proposed by Chen B et al. [8]. It is incentive compatible mechanism with some feature. MobiCent uses routing protocol which discovers the most efficient paths. When node has in-transit bundles, it will not create non-existing contacts which can increase their rewards. Ultimately, nodes are purposely not wasting their chance of bundle forwarding.

MobiCent operates on top of an underlying DTN routing mechanism, and does not rely on any specific routing protocol. When two nodes meet, they exchange metadata on the packets. Using information exchanged, each node in DTN takes decision on packet forwarding to other nodes. Packets are forwarded based on their priority which is given by the node. The amount of data that can be transferred in a single contact is dependent on the duration of the opportunistic contact. Various DTN routing protocols differ mainly on how each packet's priority is determined. In the simplest version, all packets have the same priority. MobiCent works by setting the client's payment and the relays' rewards so that nodes will behave truthfully. Therefore, nodes will always forward packets without adding phantom links, and never waste contact opportunity unless the reward is inadequate or it is the decision of underlying routing protocol. As a result, the (best) forwarding paths that should be discovered by the given routing protocol through replication and forwarding will be discovered.

D. IPAD Mechanism

An incentive and privacy-aware data dissemination (IPAD) scheme for opportunistic networks (OPPNETs), exploit how to protect mobile nodes:

1. Identity privacy
2. Location privacy
3. Social profile privacy and

Provide a secure incentive for privacy-aware data dissemination proposed by Rongxing Lu et al. [9]. Aiming at addressing the above challenge, a new credit based Incentive and Privacy-Aware data Dissemination scheme, called IPAD, for OPPNETs. In IPAD, each node holds a family of un-linkable pseudo-IDs and periodically changes its current pseudo-ID for preservation of privacy. When a source node sends a time-valuable data to a group of social friends, it also attaches an incentive to the bundles. Incentive is used to enforce the selfish nodes to participate in the bundle forwarding. This improves the packet delivery ratio and average time in OPPNETs.

E. TIS Mechanism

Threshold credit based incentive mechanism called TIS is proposed by Jun Zhou et al. [10]. Modified model of population dynamics is the backbone of this mechanism.TIS also efficiently prevent the node compromise attacks, maximize vehicular nodes' interests and enforce the cooperation among intermediate nodes. For the credits TIS realizes the fairness of possessing the same opportunity to forward the packets. TIS use time order preserving aggregated signature scheme. Resisting the layer adding attack which is launched by the collusion of intermediate vehicles can be easily solved by TIS. In vehicular DTN, TIS provides:

1. High reliability
2. High delivery ratio &
3. Low average delay

To efficiently resist targeting oriented node compromise attack and realize fairness among vehicles, based on the modified population dynamics model is proposed in threshold credit based incentive mechanism.

F. Win-Coupon Mechanism

Win-Coupon mechanism was proposed by Xuejun Zhuo et al. [11]. It uses the concept of Reverse Auction which is based on incentive mechanism to help cellular traffic offloading. It considers the users' delay tolerance and offloading potential. In this mechanism the role of buyer is associated with the network operator. Buyer offers coupons to users in exchange for them to wait for some time and opportunistically offload the traffic. Users send bids along with their request messages to the network operator. Each bid

includes the information of how long the user is willing to wait and how much coupon he wants to obtain as a return for the extra delay. Then, the network operator infers users' delay tolerance. In addition, users' offloading potential should also be considered when deciding the auction outcome. Historical parameters are collected like users' data access and mobility patterns and their future value can be predicted by conducting network modeling, and then based on the information, users' offloading potential can be predicted. The optimal auction outcome is to minimize the network operator's incentive cost subject to a given offloading target according to the bidders' delay tolerance and offloading potential. Allocation and pricing are the two steps in Auction. In the allocation step, the network operator decides which bidders are the winners and how long they need to wait. In the pricing step, the network operator decides how much to pay for each winner. Finally, the network operator returns the bidders with the auction outcome that includes the assigned delay and the value of coupon for each bidder. The winning bidders obtain the coupon, and are assured to receive the data via cellular network when their promised delay is reached.

G. COUPONS Mechanism

The Coupons scheme was proposed by Garyfalos et al. [12] and it is quite different from conventional incentive schemes, as it does not address the issue of incentives in its general form as most schemes do, but from an application scenario perspective. Here, the incentive is contextual and is based on an ordered list of unique IDs [13]. ID is appended to messages. Coupons stimulate cooperation on the application layer. The Coupons scheme also focuses on data sharing through opportunistic contact. It is designed for providing content sharing by stimulating adaptive localized interactions between potential users. Data dissemination is achieved by implementing some mechanism on top of basic flooding. Typically, the information is continuously broadcast as a user (assumed to be independent) moves and comes into contact with another user. A positive acknowledgment from this user triggers the transmission of the coupon via a three way handshake based pull model or preconfigured user profiles. Users are stimulated in relaying their content in a pyramid like manner, up to the destination. A feedback based back-off mechanism is implemented to achieve bundle forwarding. Thus, Coupons promote cooperation at the network layer too. In Coupons, every node (independent user) is assigned a unique ID, then shares a coupon as it comes in contact with an immediate surrounding neighbor, building an ordered list of unique IDs appended to a message, which in turn determines the forwarding path to the destination. A node that successfully participates in the packet forwarding is rewarded a credit (in the form of a coupon). The users residing at the top of the pyramid receive more credits than those residing at the bottom. Nodes are naturally motivated to participate in packet forwarding to earn as many credits as possible. Scalability is very high in COUPONS. Coupons can efficiently deal with attacks when a malicious node cheats by attempting to deviate from the defined mechanism in order to obtain more credit and when a set of malicious nodes aim to unbalance the system by exploiting a weakness of the algorithms.

H. IAR Mechanism

The incentive-aware routing (IAR) mechanism proposed by Shevade et al. [14] is the first practical TFT (tit-for-tat) based incentive mechanism for DTN. In this scheme (referred to as TFT-for-DTN), TFT uses a DTN routing to optimize the routes when all nodes in a DTN are cooperative, as well as a selfish DTN routing to allow selfish nodes to optimize their own individual performances while conforming to TFT constraints [13]. In the latter, every node uses a kind of Open Shortest Path First (OSPF) based link state routing to keep track of the information about links. As a result, TFT for DTN controls the selfish behavior of DTN nodes at Network Layer. Packet acknowledgment is a sign used by a node to justify that the next hop has successfully achieved its packet forwarding task. Hence, rewarding good behavior with equal reciprocal service while ignoring misbehavior. As a result TFT for DTN shows a symmetric role. As a TFT based incentive mechanism, TFT for DTN does not require trusted third party. However, in TFT for DTN, when using the selfish DTN routing to send packets from source to destination, the source route is

digitally signed by the sender. Hierarchical identity based cryptography (HIBC) is used for signature. Thus, digital signatures are used for content integrity checks and for ensuring the security of the forwarding path. In IAR mechanism, good or bad behavior reciprocates only between neighbors.

IV. COMPARISON

In Section III we have analyzed different credit based incentive mechanisms and in this section comparative study will be presented. The basic idea, advantage and disadvantage of each protocol will be listed qualitatively. At last, we will present our understandings about them. Table 1 shows a comparison of credit based incentive mechanisms.

From the comparison we can draw our understandings:

1. Mostly credit based incentive mechanisms are depends on trusted third party.
2. Limited energy (i.e. battery power) and limited buffer space of DTN nodes are the main reasons for the selfish behavior of DTN nodes.

Table 1: Comparison Of Credit Based Incentive Mechanisms

Credit Based Incentive Mechanisms	Basic Idea	Advantage	Disadvantage
SMART [6]	1. Single copy (unicast) and Multi-copy (multicast) data forwarding 2. Layered coin provides virtual electronic credit as an incentive	Scalability is very high	1. Require trusted third party 2. Digital signature as aggregation has chain signature is the communication overhead
Pi [7]	1. Combined approach of credit and reputation 2. For successful packet delivery to destination, helping nodes gets credit as well as reputation 3. For unsuccessful packet delivery to destination, helping nodes only gets reputation from trusted third party	Anti-black hole attack	1. Require trusted third party 2. No multi-copy data forwarding
MobiCent [8]	Incentive compatible approach allowing routing protocol to discover the most efficient paths	Resisting edge insertion attack & edge hiding attack	Require trusted third party
IPAD [9]	Incentive strategy which is fair as well as with protection of mobile nodes privacy for efficiently disseminating a time-valuable data	Provide mobile nodes: 1. Identity privacy 2. Location privacy& 3. Social profile privacy	Require trusted third party
TIS [10]	Use of modified population dynamics model as the basis of Incentive scheme	Resisting the layer adding	Require trusted third party

		attack	
Win-Coupon [11]	Nodes which helps in forwarding the packets gets currency as Incentive and nodes sending packets for themselves loose currency	Anti-hiding attack	Require trusted third party
Coupons [12] and [13]	Incentive is contextual and is based on an ordered list of unique IDs appended to messages	Scalability is very high	Charging rate is application dependant
IAR[13] and [14]	It uses DTN routing to optimize the route when all nodes are co-operative. And selfish DTN routing when selfish nodes are present	Does not require trusted third party	Reciprocates good or bad behavior only between neighbors

V. CONCLUSION

In this paper, we present the different Credit based Incentive protocols and analyze them according to their basic idea, advantages and disadvantages. Selfishness is the critical issue in DTN. DTN still demands more research for selfish behavior of nodes so that selfish nodes also should take part in the delivering the packets to the destination. There are many open issues in the DTN [15] which are stated below:

1. Key Management
2. Handling Replays
3. Traffic Analysis
4. Routing Protocol Security
5. Multicast Security
6. Performance Issues

Security of DTN nodes and Energy of DTN nodes are the two major areas in DTN which demands more research work in future.

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