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A Survey on Delay Tolerant Network in Disaster Management

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***Abstract* - Natural calamity seizes the conventional network infrastructure and leaves people to ordeal. In such cases where disruption of network infrastructure is obvious, use of Delay Tolerant Network (DTN), in which volunteers carry inter-connected smart phones and personal digital assistants (PDA) in well-coordinated manner, looks promising for relief and rescue operations. This paper takes a survey on Delay Tolerant Networks by touching some of the fundamentals and taking a quick glimpse of the basic architecture and routing techniques of DTN. It also takes a quick note on some commonly used simulators in this field of study.**

Keywords - Delay Tolerant Network, Candidate Device, Bundle Layer, Node, Contact, Relay.

I. INTRODUCTION

Human activities are severely affected by large-scale natural disasters like cyclone, earth-quake, flood etc. and such natural disaster makes infrastructure for conventional communication crippled. Some places on the earth are so remotely located that even in normal days there is no network infrastructure. So under such emergent-circumstances when everyday communication services like WLL, CDMA, GSM, PSTN etc. becomes non-functional, then there is a huge requirement for deployment of communication networks. The deployed network will be a great help in establishing the need of communication and connectivity capabilities for both survivors and rescuing-volunteers in rescue and restoration of normalcy of life.

Due to vulnerable network infrastructure during natural calamities, end-to-end connectivity cannot be assured and hence working under these circumstances becomes difficult. And this leads to evolution of newer network type which is independent of end-to-end connectivity, called the Delay Tolerant Network (DTN). DTN is also known as intermittently connected mobile network, as it is a wireless network in which a fully connected path from source to destination is very unlikely to exist. Effective forwarding based on a limited knowledge of the current contact behavior of a node is often challenging. Therefore in these networks, message delivery relies on opportunistic routing where a node uses store-carry-and-forward paradigm to route the messages in network. Delay Tolerant Network is an advanced approach to computer network architecture which aims at addressing the technical issues in heterogeneous networks that lack in continuous network connectivity. The wireless DTN technologies can be heterogeneous in nature, including not only radio frequency (RF), but also Ultra-wide bands (UWB), free-space optical and acoustic (sonar or ultra-sonar) technologies. DTN depends on mobile devices like smart phones, PDA etc. to carry data between the nodes and performance of routing data only depends on whether nodes come in contact with each-other or not.

II. NETWORK CHARATERISTICS

DTN consist of different computing systems participating in the network establishment and performance, which are termed as nodes. Some nodes are connected together via one-way link, which may go up and down over time because of mobility, failure and other events. The source node has opportunity to send data to other end when link is up and this is called as contact. Depending on the location of the node in the network, one or more than one contacts may be available depending on set of times in contact schedule. The characteristic of a DTN is to use the network by forwarding the message over each hop, which is buffered at intermediate nodes and result in messages to wait till the next hop is available, which may be a long period of time.

For transferring the messages from one mode to another, the amount of time taken can be divided into four parts: *Waiting Time:* it is the amount of time for which a message must wait in between, when it arrives at a node and when the contact with next node becomes available; *Queuing Time:* it is the time which takes to drain the queue of higher priority messages; *Transmission Delay:* it is the time taken for all bits of the message to be transmitted, which is to be computed from the contacts data rate and the message length; *Propagation Delay:* it is the time which a bit takes to propagate across the connection and it totally depends on the link technology.

III. NETWORK ARCHITECTURE

In disaster scenario for setting up communication and connectivity, we should use lower range and cheaper devices at the bottom layer towards building the next higher ones with higher range and costlier devices when it is not possible with the lower layer. As such devices are very ease at deployment compared to higher range of devices which require proper infrastructure for deployment and increases the cost of disaster-management as well as requires more time for set-up and in such circumstances time is an important constraint. For example “VSAT Technology” which is primarily deployed for development purposes rather than emergency response or post disaster relief and it is very expensive to deploy also.

In any environment where network infrastructure is disrupted and long disconnections are rule, DTN can be one of the feasible options. The DTN architecture basis lies with that of the Interplanetary Internet and this architecture embraces the concepts of occasionally connected networks that may suffer from frequent partitions. A DTN is a network of regional networks i.e. it is an overlay on the top of regional networks, including the internet. And this overlay is called as bundle layer, which exists at a layer above the transport (or other) layers of the network on which it is hosted and below application. Devices implementing the bundle layer are called DTN nodes. It has persistence storage and includes hop-by-hop transfer of reliable delivery responsibility and optional end-to-end acknowledgement. Bundles are also called as messages and comprises of three things: source node's user-data, control information (like source nodeID, destination nodeID, TTL) and a bundle header.

Internet protocols do not work well for some environments because of some fundamental assumptions built into the internet architecture like

- End-to-end path should exist between source and destination through-out the session.
- There is relatively very small end-to-end loss.
- All network elements should support TCP/IP protocol.
- Applications do not have to take care of communication performance.
- Most security concerns are sufficiently met by end point-based security mechanism.
- Selecting single route between sender and receiver is sufficient for achieving acceptable communication performance.

And these limitations of internet architecture laid the need for DTN architecture. And since DTN is an alternative for internet architecture so it relaxes most of Internet Architecture assumptions.

In this vulnerable infrastructure, battery-powered wireless personal mobile communication devices (PDA, Smart-phones) having powerful processors, high storage capacity, with GPS and multi-radio interfaces can be candidate devices. These devices are spread across the environment by relief workers which forms delay tolerant network. These candidate devices which are held by volunteers, work on store-carry-and-forward paradigm to route the messages. Complete message or message chunk is stored and carried by a DTN-node and is forwarded when contact is established with next node closer to destination node. These contacts are of following major types: *Persistent Contact:* it is always available; *On-Demand Contacts:* it requires some actions to instantiate and once instantiated then functions like a persistent contact; *Intermittent-Scheduled Contacts:* it is an agreement to establish a contact at a particular time, for a particular duration; *Intermittent-Predicted Contacts:* these are based on no fixed schedule, but rather are predictions of likely contact times and durations based on a history of previously observed contacts or some other information.

IV. ROUTING STRATEGIES

Although the connectivity of the nodes is not maintained constantly but it is still desirable to allow communication between nodes since most of the network is maintained by nodes only when they come into the transmission range of each other. Therefore it is necessary to provide a routing protocol which tries to route packets throughout the times the link is available among the nodes. But this can't be done by standard routing algorithms which assume that the network is connected at most of the time.

Based on the strategies used by source to find the destination, DTN routing Strategies are divided into two categories. But there are still some strategies which are difficult to place in any of them, like all other classifications.

A. *Flooding Strategies:* Flooding strategy primarily relies on each message to enough nodes i.e. each message is sprayed to the maximum number of nodes possible in the network so that destination receives it. In this strategy multiple copies of each message is delivered to a set of nodes called a relay. These relays store the messages till they are connected to destination and during this event message is delivered to the destination. Some earlier works fall in this category even when "Delay-Tolerant" term was not coined and was studied in context of mobile ad-hoc networks [MANET]. The basic protocols following this strategy do not require knowledge about the network as it uses message replication to increase the probability of messages getting delivered.

B. *Forwarding Strategies:* This strategy takes more traditional routing approach to route the data in DTN and hence has to rely on knowledge about the network to select the best path to the destination and the message is then forwarded from node to node along this path. Based on location based routing by assigning metrics to the nodes or by assigning metrics to links, a suitable path can be found. Since they use best path to send the message, so they send a single message and don't need to replicate.

TABLE I depicts a brief comparison of different algorithm, their assumption and simulation model. From table we can observe that in Epidemic routing a source tries to reach the destination by flooding message copies to the different nodes in contact. Where as in Prophet, Practical routing and MaxProp only single copy of message is send to the network based on the probability from previous meeting. And in Adaptive routing and Spray-and-Wait limited number of copy of messages are sent to the network based on hop count from source and contact duration and randomness. And we can also point-out from the table that MaxProp is the only routing algorithm which gives acknowledgement to the source that message has been delivered to the destination following the same path. This acknowledgement is done at high processing cost and resource utilization.

V. SIMULATIONS

Use of simulator for experimental study is necessary as it establishes the particular set of conditions artificially, which

TABLE I. Comparison of Algorithms

Algorithms followed					**Assumptions**		**Simulation Model**	
Name	***Number of copies***	***Decision based on***	***Drawbacks***	***Delivery Ack***	***Buffer-size***	***Bandwidth Capacity***	***Simulator***	***Mobility***
Epidemic Routing	Unlimited	Flooding	High resource usage	-	Limited	-	NS-2	RWP
Prophet	Single	Probability from previous meeting	High message overhead	-	Limited	-	ONE	RWP
Adaptive Routing	Limited	Estimation based on hop count from source and contact duration	Continues spreading after message delivery	-	Sufficient	Sufficient	NS-2	RWP
Practical Routing	Single	Best path found according to the previous meeting of nodes	High transmission overhead due to routing table maintenance	-	Limited	Limited	ONE	Real Trace
MaxProp	Single	Previous node meeting and updated route estimation	High processing cost	Yes	Unlimited(own) Limited(other)	Limited	ONE	Real Data
Spray and Wait	Limited	Randomness	Random Decision making	-	Sufficient	Sufficient	ONE	RWP, RD, RW

could have existed in reality. One of the main advantages of using simulator compared to real networks for testing is that a simulated environment is much cheaper to set up. It is usually faster and consumes less set up time because simulator needs only topology description. It takes considerably less physical space, since only a few simulator machines, cables and switches or routers are needed and to be installed. In simulation process environment can be easily controlled and hence the results are easier to compare because of more controlled environment.

The downside of using a simulator is the fact that simulator provide us artificial simulations and since it is artificial so its result may or may not tally with the real-time simulation process and if not then report of such simulations, may mislead instead of helping in disaster planning. Simulator has its own code base, which means that any protocol to be tested should inter-operate with the simulator. There are two most commonly used simulator tool in computer network: Network Simulator (NS) and ONE Simulator Tool.

A. Network Simulator [NS]

The network simulator tool is a generic tool which has large use base and support. It can be utilized for many purposes. Almost all new research on computer networks uses this tool. However its generic nature also means that there is lack of special features for individual protocol. The interface between the simulator and live-network is provided by a collection of objects including “Tap Agents” and “Network Objects”. Tap agent embed live network data into simulated packets and vice-versa. Network object are installed in tap agents and provides an entry point for the sending and receipt of live data. There is a “Real Time Scheduler” in NS that implements the soft scheduler which ties event execution within the simulator to real time. Handling packets in live simulations, for this purpose NS uses “Tap Agent” class.

From TABLE I, we can observe that Epidemic Routing and Adaptive Routing based on RWP [Random Waypoint Model] mobility model works on Network Simulator [NS-2].

B. ONE Simulator Tool

ONE Simulator is meant for DTN related MANET simulation as this is its sole focus. So, for such scenario’s it can provide more support and be more realistic than NS. Delay-tolerant Networking (DTN) enables communication in sparse mobile ad-hoc networks and other challenged environments where traditional networking fails. The new routing and application protocols has shown their performance is highly dependent on the underlying mobility and node characteristics. In many scenario evaluation of DTN routing and application protocols require suitable simulation tool. Opportunistic Networking Environment (ONE) simulator has been specifically designed for evaluating DTN routing and application protocols. It allows users to create scenario based upon different synthetic movement models and real-world traces and offers a frame work for implementing routing and application protocols.

From TABLE I, we can see that Prophet and Spray-and-Wait works on ONE simulator tool based on RWP mobility model, where as Practical Routing and MaxProp works on ONE simulator tool based on Real trace and Real Data mobility model respectively.

There are certain numbers of parameters which are relevant for checking the performance of proposed system using simulators and their values for the system can tell us a lot about its functioning and thus deployment for real-time systems. These parameters are:

- *Delivered Message:* These are the total number of messages that are successfully delivered to the destination from source.
- *Dropped Messages:* These are the total number of messages dropped by the nodes while delivering to the destination.

- *Overhead Ratio:* It is negation of number of messages relayed to the number of messages delivered. Low value of overhead means less processing required while delivering the relayed messages. Objective of the algorithm is to minimize the value of overhead.
- *Latency Average:* it is the average of messages delayed from creation to delivery. Latency is a very important parameter as it constitutes to the network speed. The term latency refers to any kind of delays typically incurred in processing of network data. A low latency network link is that which normally experiences small delay, whereas high latency usually experiences long delays. In DTN latency is high due to its network value.
- *Buffer-time Average:* it is the average time of message for which that remains into the buffer of the node.

VI. OPEN ISSUES

Delay-tolerant Networks have grab attention of network researchers for the last few years as it has an extra advantage over unstated-internet architecture assumptions and being heterogeneous in nature. Till date, DTN has mostly been explored for uses in under-developing or developing regions and people have been successful in deploying it for challenged regions. Devices working in DTN are mostly battery operated (PDA, Smartphone) so message replication, over-head ratio, buffer time etc. should be reduced to decrease consumption of limited resources in the network and for that proper strategies and approach should be taken as well as relevant algorithms has to be proposed.

For Disaster-Management system, some API has to be developed, which contains geographical maps and detail infrastructure of the disaster hit area which can help rescue and relief team to make strategies and proceed in a planned approach. DTN based devices should be developed which can provide internet facility so that it can be helpful for the people in both normal and emergent situation. This will enable people living in disaster prone zone to help each other in distress before actually relief and rescue team has started their operations.

VII. CONCLUSION

This paper has discussed different features and properties of Delay Tolerant Network. DTN enables people to take a planned approach in disaster affected area where network infrastructure can vary from bad to worst while coping under harsh conditions. It can also span across multiple networks. DTN promises to enable communication between challenged networks and hence is an attempt to extend the reach of networks. A survey on DTN fundamental architecture and routing strategies followed by a discussion about the most commonly used simulator tools has been presented in this context. In the end, it may be pointed that this paper opens up a wide scope of investigative studies in this area, with a goal of harnessing the flexible architecture of DTN towards an all-encompassing model in which "one-size-fits-all".

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REFERENCES

[1] Debanjan Das Deb, Sagar Bose and Somprakash Bandyopadhyay, COORDINATING DISASTER RELIEF OPERATIONS USING SMART PHONE / PDA BASED PEER-TO-PEER COMMUNICATION, International Journal of Wireless & Mobile Networks (IJWMN) Vol. 4, No. 6, December 2012.

[2] S.Saha, V.K. Shah, R. Verma, R. Mandal and S.Nandi, Is It Worth Taking a Planned Approach to Design Ad-hoc Infrastructure for Post Disaster Communication?, in Proceedings of the ACM CHANTS'12, co-located with MobiCom 2012, August 22, 2012, Istanbul, Turkey.

[3] Evan P.C. Jones, Paul A.S. Ward, "Routing Strategies for Delay-Tolerant Networks" H. Luo, R. Kravets, T. Abdelzaher, The-Day-After Networks: A First-Response Edge-Network Architecture for Disaster Relief, NSF NeTS FIND Initiative, 2006-2010.http://www.nets-find.net/Funded/DayAfterNet.php

[4] Md Yusuf S. Uddin, David M. Nicol, Tarek F. Abdelzaher "A POST-DISASTER MOBILITY MODEL FOR DELAY TOLERANT NETWORKING", Proceedings of the 2009 Winter Simulation Conference

[5] M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin, and R. G. Ingalls, eds. A. Pentland, R. Fletcher, and A. Hasson, Daknet: Rethinking Connectivity in Developing Nations, in IEEE Computer So ciety, Vol. 37, pp. 78-83, 2004.

[6] A Delay-Tolerant Network Architecture for Challenged Internets, Kevin Fall, Intel Research, Berkeley.

[7] Sujoy saha, sushonan, anirudh sheldekar, rijor joseph c, aratya mukherjee, and subrata nandi, "Post Disaster Management Using Delay Tolerant Network" Recent Trends in Wireless and Mobile Networks Communications in Computer and Information Science Volume 162, 2011, pp 170-184.

[8] Shyam Kapadia, BhaskarKrishnamachari, and Lin Zhang"Data Delivery in Delay Tolerant Networks:A Survey"Cisco Systems Inc., San Jose, CA 2006.

[9] V. Cerf, S. Burleigh, A. Hooke, L. Torgerson "Delay-Tolerant Networking Architecture "Network Working Group Google/Jet Propulsion Laboratory, April 2007.