Future of Delay Tolerant Networking

Delay tolerant networking (DTN) has emerged as new technique for computer network architecture. This technique can solve the issue of discontinuous network connectivity by using its efficient data forwarding algorithm. Unlike traditional data forwarding algorithms, DTN uses the store, carry and forward technique to increase the reliability of network and decrease latency in data transmission.

Architecture of Delay Tolerant Networks

Considering scattered mobile and ad-hoc network where we cannot guarantee end to end path between source and destination the traditional protocols such as TCP and UDP cannot transfer the information efficiently. TCP assumes that the packet once send from source will get its route to destination and its reliability mechanism assumes the RTT to be cheap. For less RTT if packet is lost in the network then retransmission can be done without affecting the latency and this mechanism is very effective for network with small RTT. However considering some applications such deep space networking the RTT is large and TCP mechanism will result in more latency which is indeed not efficient. Considering UDP mechanism the source to destination data transfer is not reliable which further cannot be applied in application for deep space communication and other network where reliability and content delivery in time are cardinal aspects.

DTN can efficiently solve the problem of very large delays and internment and scheduled links with its reliable architecture. To manage the irregular connectivity of nodes DTN uses store-carry-forward method. The nodes will store the message and will wait for proper communication opportunity **[1].** Once it gets in contact with other node which can send the packets to destination it will generate copy of packets and will send to that node. The receiving node will also do the same process and will send packet to next hop. However if the next hop is not available, because of congestion or if the link is down, the node will store packet into its buffer until the link is available or another link with less latency is found. In this way end to end retransmission can be avoided and instead retransmission will be between nodes where link failure occurred. Moreover for dynamic topology if node finds another route with less latency then it will transfer packet to that node so that it can reach destination quickly.

The mechanism used by DTN to utilize the store-carry and forward technique effectively is bundle protocol explained by Upendra Malekar **[2].** In DTN we can hold on to the data in each hop and the node can take responsibility to forward the data into network. The goal here is to maintain the gain we got, as we do not want to do the retransmission from source. If we consider the case of communication between Mars Rover and earth, when the rover finds some information on mars it will send it to earth's orbit and from there to the base station on earth. Now if there is some congestion in the links at base station we will lose the data and it is indeed not efficient to ask the rover to transmit the data again. This kind case scenarios propelled the need of alternative approach such as DTN.

In DTN we give custody to the intermediate nodes and thereby to the network, as described in bundle protocol, that means acknowledgements can be sent back within the network and not end to end which not only will increase the efficiency of network but also will decrease the latency due to end to end retransmission. The protocols such as FTP can take from 6 to 22 round trips before it moves its first byte of data. For setting control connection and getting logged in, FTP creates more overhead. Moving back and forth in highly challenged network is a big problem so instead doing that if the application can send complete information about the file to be moved such as name, authentication credentials and destination information then that data can be bundled and send across the network single time.

Routing Models for DTN

As DTN can store data in this intermediate nodes we can route taking time into account and this will give flexibility while routing. Moreover some features of DTN such as storage at intermediate nodes and dynamic topology should also be considered while designing the protocols for DTN. The routing objective is to minimize the delay and maximize throughput by taking advantage of store-carry-forward technique. Routing protocols for DTN can be broadly classified into flooding based, knowledge based and probabilistic protocols.

Probabilistic routing algorithms are based on the massage delivery probability from node to node. The massage delivery probability is calculated by considering contact duration and knowing how frequently the nodes meet **[3].** The route with more probability of successful transmission is selected based on the protocol requirement. As DTN is sparse network the probability calculation can predict efficient results and therefore more protocols considering probabilistic approaches are presented. In protocol like MobySpace there should be regularity in contacts of the nodes and that gives more realistic appearance to this protocol. As the nodes can be assumed in three dimensional space if we consider each axes be a location we can calculate results taking less dimension in consideration. Having each axes to be a contact grows the dimension with number of nodes in this case probabilities of contacts are updated based on each node’s history of contacts. Matrices with this contact values are calculated and optimal path for forwarding packets is decided. However this protocol has some limitations such as with increase in number of node the complexity of protocol increases

Some popular algorithms like PROPHET consider probabilistic routing protocol using history of contacts and transitivity. This protocol cleverly implements the concept of transitivity on contact history and tries to find feasible way to destination. Each node maintains a matrix called “delivery predictability matrix P(a,b)” for every known destination ‘b’. When two nodes meet in network each node will transfer the information it has to other node which in case the stored matrix at node. Each node will update its information if received matrix data indicates higher delivery predictability to destination node. According to Jae-Choong Nam **[4]** if we consider scenario where node A is source, node D is destination and node b is node in contact with A. Then node A will transfer the data to node B only if $P(a, d) < P(b, d)$. After sending data it will update its matrix fields indicating that it was in contact with node and it has transferred one copy of data to node B. As $P(a, d) < P(b, d)$ it is possible that the node B will transfer that packet to some other node which will lead it to destination. The value of probability that at least one image of the message is transferred to the destination is set as PMD. Node A will update its status by calculating the probability PMD = 1 - (1- PA)(1- PB). This value is useful in managing the buffer size for node. As high PMD value indicates more probability of successful transmission to destination, the packets with high value can be dropped in case of buffer overflow. Thus this protocol not only gives estimation of feasible route to destination but also gives estimation for buffer management.

Some protocols consider the contact duration as important aspect to determine possible route to destination. As described by Chen Yu **[3]**, merely getting in contact is not sufficient to transfer data. The contact duration should be sufficient in order to transfer data from one node to other. Contact duration denotes the probability that the message was transferred successfully when the respective nodes met in past. The protocol specifies minimum time that is to be considered in order to declare successful data transfer. If the contact duration is less than that time then it can be neglected. The history of meeting frequency and contact duration is combined to give more efficient algorithm. This method gives overhead control to the protocol by filtering nodes which cannot have sufficient contact duration. Considering two nodes A and B with same frequency of meeting with source node S, applying given protocol the node (A or B) with higher value of contact duration will receive packet from node S. Moreover, the source node will generate copies of the packets present in its buffer and will send it to the node satisfying the criteria specified by algorithm and also by increasing probability of packet delivery to destination node. Buffer management policy is managed by first in first out rule. This approach improves the efficiency of protocol giving more accurate prediction of successful data transfer and reduces network overhead.

DTN knowledge based data routing models can be considered as reactive and proactive **[5].** For reactive routing each node has data tables for other nodes and data table get updated whenever node encounters contact with other nodes. Moreover nodes are not dependent on their change of location to transfer data. In proactive routing the path of nodes can be modified to establish contact with other nodes. The node which is given custody of bundle can look for the information of other nodes which have more probability of reaching destination and can modify its way according to that information. This type of routing requires some extra information about other nodes such as their previous encounter with other nodes and contact duration for those encounters. For knowledge based protocol the time when two nodes meet in dynamic topology is considered as contact and the information is sent from one node to other node during the contact period. Some of the knowledge based protocol assumes that all the node in network have knowledge about the contact information and the contact duration. So this protocols assumes the existence of oracle which gives some information about the network. The oracle is assumed to make decision on history of the network and the contact information of the nodes. Such protocols are not implemented in practice yet, however methods to implement this protocols are open for research.

Flooding based routing protocols focus more on the buffer management for nodes. This category of protocols is useful when we have nodes with small buffer size **[6].** Therefore according to the need of application different routing protocols can be used to get more efficiency. For example the animal tracking system based on DTN uses the probabilistic model to send information as the topology of network is dynamic and contact duration plays an important role in data transfer.

Buffer Management Strategy

DTN implement the store-carry-forward method for data transmission through network and that requires the intermediate nodes in network to have data buffer. The data buffer eradicates the end to end data retransmission. The data is temporarily stored in the data buffer of intermediate nodes if the next hop is not available. However the nodes cannot store large amount of data in network because of the limited size. There should be policy to decide in which order the packets should be dropped if buffer space is full. So buffer management strategy is important to decide when to drop the old data and accept new data.

Several methods for buffer management are proposed such as simple methods of first in first out and last in last out. However this methods does not consider the replication of message in network and the current number of copies in buffer. Taun Le and his team designed strategy for buffer management where they considered three important aspects as "relay selection strategy, message replication prioritization and message drop prioritization"**[1].** For relay selection consider a node 'k' having message 'n' in its buffer intended to send this message to destination 'z'. For each time slot the node 'k' tries to find node in its vicinity. Node 'm' near to 'k' sends its mean of expected delay EMD to k. If the equation "EMD(m,z) < EMDnew(k,z)" holds true then the message is replicated to node m.

For message replication priority this algorithm proposes novel way to calculate the number of copies generated and the number of nodes that received those copies. Initially the source gives custody of bundle to other node in path, this node then has the responsibility to replicate the message to other nodes. The node while replicating copies to other nodes will set packet replication number and packet alive time (PAT) in the header field of bundle. The replication number will get incremented when it is sent to other node and the PAT will record the alive time 'T' of bundle. Thus the replication number will indicate the number of copies distributed till time 'T'. Therefore consider a scenario when node A meets node B and tries to send packet but the buffer of node B is full. In this case the node B will first check the replication number and PAT of packets in buffer and will know the status of packets. If the replication and PAT fields are more than specified value then it will delete the packets in buffer and will accept new packets from A. In this way the buffer can be efficiently managed to increase the reliability of protocol.

Conclusion and future direction

DTN is indeed effective technology to reduce delays and improve efficiency in unpredictable network environment. DTN looks beyond the unstated network assumptions which considers existence of some path between source and destination and small end to end RTT. The application of DTN ranges from deep space networking, animal tracing to lake quality monitoring. As the technology is in developing phase, the use is also application specific rather than everyday life application. AS data is temporarily stored at nodes, it is vulnerable to attacks due to lack of security. Thus DTN has some challenges such as security issue and absence of common APIs to abridge DTN, which needs to be addressed.

Bibliography

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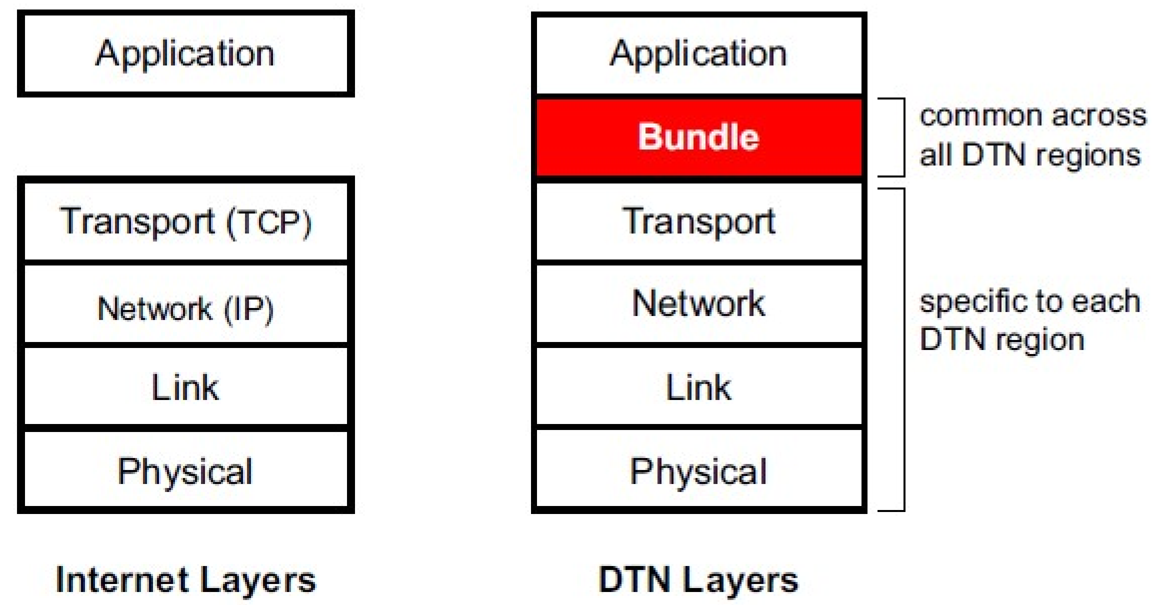

Fig 1. Bundle Layer in Protocol

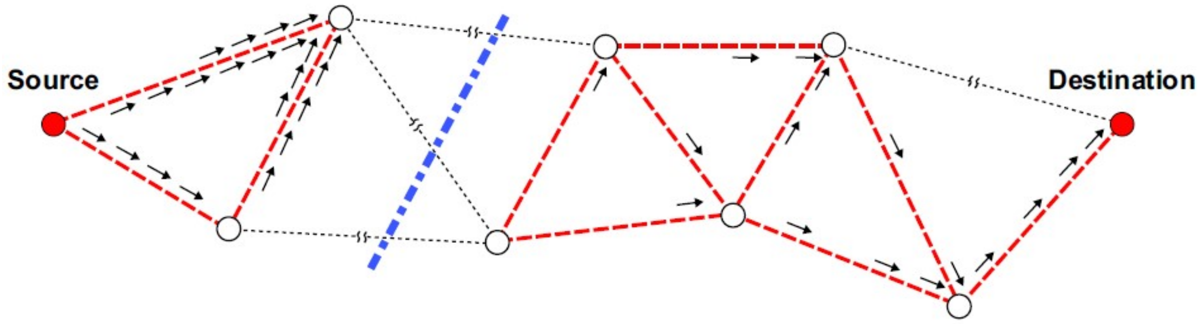

Fig 2. Scenario where link between source and destination is not available

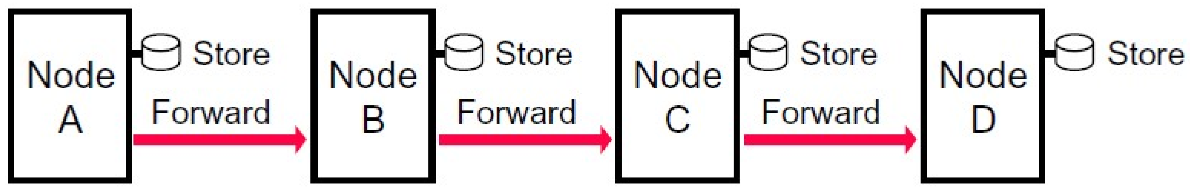

Fig 3. Store and forward policy of DTN

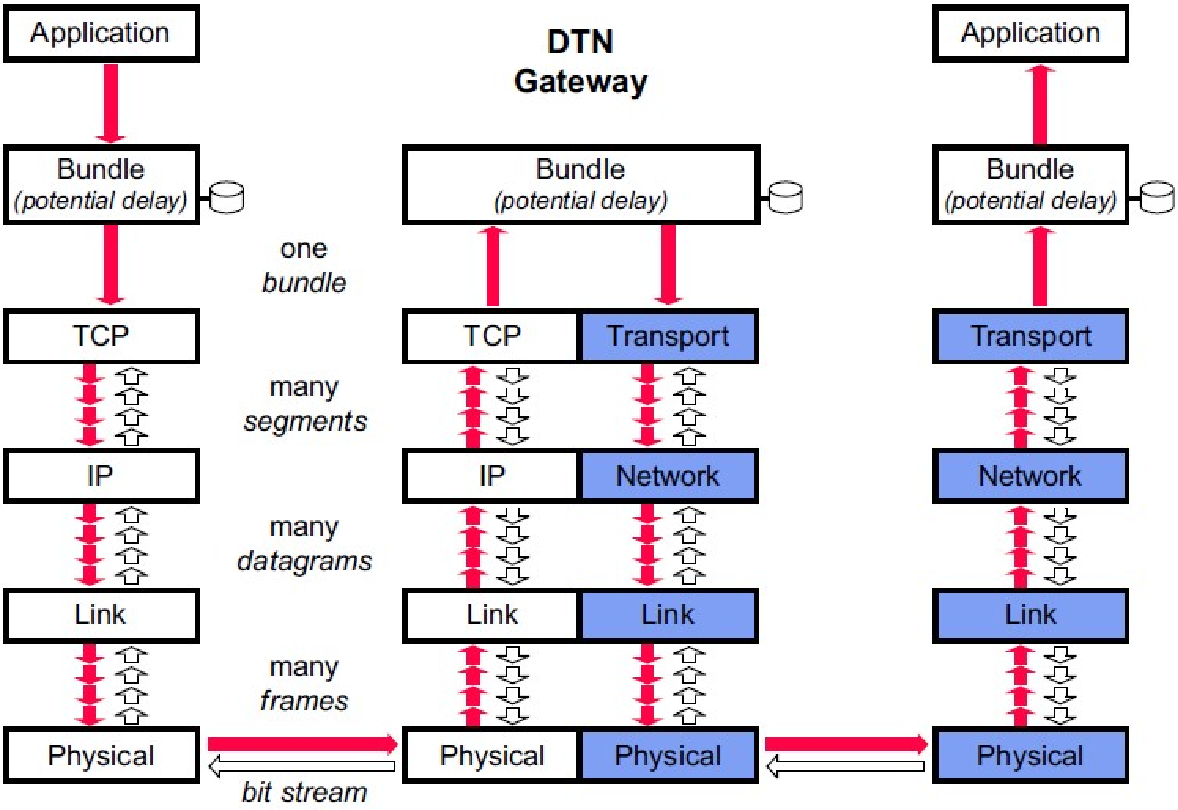

Fig 4. Communication between applications using DTN protocol