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RESEARCH ARTICLE

DELAY – Disruption Tolerant Network (DTN), its Network Characteristics and Core Applications

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Abstract—***Delay – Disruption Tolerant Architecture, DTN is meant to provide connectivity in Heterogeneous networks which lack incessant connectivity due to disruptions or considerable delays like that of networks operating in mobile or extreme terrestrial environments or planned network in space. The DTN effectively improves network communications where the network connectivity is Periodic/Intermittent and or Prone to disruptions. The Store and Forward technique via the Bundle Protocol (BP) of the Delay Tolerant Network facilitates the flow of data/information across any complex or intermittent network traffic. This study encompasses the overview of Delay Tolerant Network and its characteristics and the Use of Bundle Protocol for efficient usage of sporadic network connection along with applications of DTN.***

Keywords— Delay Tolerant Networks (DTN); Bundle Protocol; Contacts; Bytewalla; Android

I. INTRODUCTION

Initially developed for Deep Space Communication (Inter Planetary Internet), the Delay-Disruption Tolerant Network communication model can also be used in Wireless (Terrestrial) environments, both in Military and Civilian Applications. The main difference between the Space & Terrestrial environments can be accredited to the fact that the space contacts/communications are scheduled and predictable while the terrestrial one's are more opportunistic in nature [1] and the networking model like Delay-tolerant networks can provide efficient communication in spite of challenging environments. The Traditional TCP/IP Protocol suite has served well the Internet & Networking communications till today, however there are new and challenging environments and applications where the internet protocols perform poorly (or) cannot be used at all. In such crucial environments, the DTN approach can offer a viable alternative for realizing communication. Notable feature of wireless DTN feature is that, the architecture not only includes Radio Frequency (RF), but also ranges like Ultra Wide Band (UWB), Free Space Optical and Acoustic (SONAR or Ultra Sonic) technologies. Utilizing the DTN approach requires significant effort developing additional functionality and integrating them. Delay-Disruption Tolerant networks make use of "Store – and – Forward" technique within the network in order to compensate Intermittent Link Connectivity. In the DTN, the fundamental concept is an Architecture based on Internet – Independent Middleware, where the protocols at all layers are used that bets suite the operation within each environment,

with a new overlay network called Bundle Protocol (BP) inserted between application & the locally optimized communication stacks. Military applications in the DTN areas are substantial, allowing the retrieval of critical information in mobile battlefield scenarios using only intermittently connected network communications. For these kinds of applications, the DTN protocol should transmit data segments across multi – hop networks that consists of different regional networks based on environmental network parameters. Recent active research area, DTN seeks to address technical issues in the network that lack continuous network connectivity. Ex: remote areas with no proper infrastructure. With tremendous increase in usage; the wireless networks are witnessing several deployment issues across various extreme environments where they suffer from different level of link disruption depending upon the severity of operating conditions. In all the cases, the operation requirements are differently altered and their performance is negatively altered rendering them Heterogeneous nature.

II. DELAY - DISRUPTION TOLERANT NETWORKS (DTN):

The DTN networks reliably advances wireless traffic despite hostile conditions, jamming activity or moved or damaged nodes. While traditional IP networks relay on end-to-end connectivity, which means that data can be sent only when there is an identifiable path all the way to the destination, DTN continues to advance data even when there's no complete, identifiable path to the destination. DTN uses intermittently available links to communicate opportunistically. The information are organised into bundles rather than packets and routed through intelligent "custodians" that augment traditional routers. These custodians advance the bundles to the next node on the way to their destination. The network uses variety of communication nodes, such as wireless, satellites, vehicle- mounted and unmanned aerial vehicle, to continuously advance message traffic even when there's an obstacle in the path that would stop traffic in the traditionally network. The delay tolerant networks makes the network to continue its function reliably in the environment where communications are most challenging and most critical and the message traffic continues to flow despite geographical or structural or malicious disruptions. The DTN Architecture is designed to effectively operate as an overlay on top of regional networks or as an Inter Planetary internet. Moreover, the Delay Tolerant Network can overcome problems characterized by Long – Delays, Asymmetric Data Rates, Intermittent Connectivity, High Error Rates due to extreme environments, distances encountered in Space communication at Inter – Planetary scale competently when compared with the traditional Internet suite.

III. DTN NETWORK CHARACTERISTICS:

DTN network architecture is composed of computing systems participating in the network called "Nodes". One-way Links connects some nodes together. These links may go Up & Down over time, due to mobility, failures (or) other events.

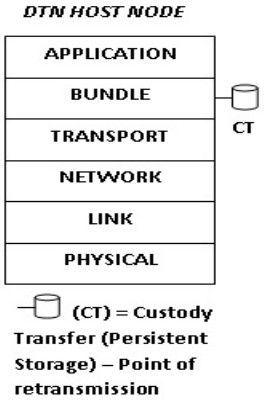

Fig 1: A DTN Node

When the link is up, the source node has an opportunity to send the data to other end. In DTN, this opportunity is called "Contact" [2]. More than one contact may be available between a given pair of nodes. For ex: a node might have both High-Performance, expensive connections and a Low-Performance cheap connection simultaneously for communication with the same direction. The "Contact Schedule" is the set of times when the Contact will be available, (i.e.) upon considering the Contact's in Graph Theory, it is a Time-Varying Multi-Graph. The DTN architecture proposes to use this network by forwarding the complete Data/Message over each

hop. These Messages/Data will be buffered at each intermediate node, potentially on Non-Volatile Storage. This enable messages to wait until the Next-Hop is available; which may be a long period of time [3].

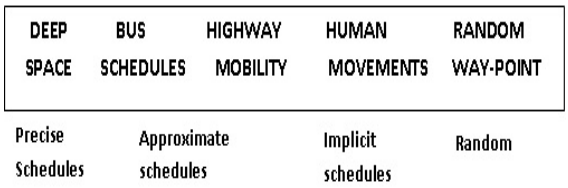

Fig 2: Contact Schedule Predictability

Unlike the TCP/IP, the DTN does not assume a continuous end – to – end connection. In its design, if a destination path is un-reachable, the data packets are not discarded but instead each network node keeps custody of the data as long as necessary until it can positively communicate with other node which ensures that the information does not get lost when no intermediate path to the destination exists. The DTN acts as an overlay above Transport Layers of the networks it interconnects and provides key services such as in-network data storage and retransmission, interoperable naming, authenticated forwarding and a coarse-grained class of service. TCP/IP suite functions poorly when faced with very long delay paths and frequent network partition. These problems are aggravated by the end nodes that have Severe Power constraints or Memory constraints. The DTN network overcomes the above hindrances structured around optionally- reliable asynchronous message forwarding of end-to-end connectivity & node resources.

IV. TYPES OF CONTACTS:

The Delay – Disruption Tolerant networks depends upon 'Contacts', which can be defined as the period of time or interval during which the Network & Communication capacity is highly positive, and the capacity can be considered as a constant. If the Contact and their volumes are known ahead of time, intelligent routing and forwarding decisions can be made (optimally for small networks. The Contacts in the Delay Tolerant Networks typically fall into one of several categories, based largely on the predictability of their performance characteristics & whether some action is required to bring them into existence. The following are the major types of contacts:

i. PERSISTENT CONTACT

Persistent Contacts are always available (i.e.) no connection initiation is required to instantiate a Persistent Contact. An 'always-on' Internet connection such as DSL (or) Cable Modem Connection is a representative of this class.

ii. ON – DEMAND CONTACT

On – Demand Contact requires some action in order to instantiate, but then function as persistent Contact until it's terminated. A dial – up connection is an example of an On – Demand Contact.

iii. INTERMITTENT – SCHEDULED CONTACTS

A Scheduled Contact is an agreement to establish a Contact at a particular time, for particular duration ex: A Link with low – earth orbiting satellite. For the networks with substantial delays, the notion of the 'Particular time' is delay – dependent ex: a single scheduled contact between Earth and Mars would not be at the same instant in each location, but would instead be offset by the (non – negligible) propagation delay.

iv. INTERMITTENT – OPPORTUNISTIC CONTACTS

The Opportunistic Contacts are not scheduled, but rather present themselves unexpectedly ex: an unscheduled aircraft flying overhead and beaconing, advertising its availability for communication, would present an opportunistic contact.

v. INTERMITTENT – PREDICTED CONTACT

Predicted Contacts 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. This is an active research area [4].

V. BUNDLE PROTOCO (BP)/LICKLIDER TRANSMISSION PROTOCOL:

The overlay network approach of the Delay Tolerant Network is represented by the Bundle Protocol (BP). The bundle layer forms a place on top that employs persistent storage to help combat network interruptions, forming a store- and – forward overlay network. The Bundle Protocol suite is intended to consist of group of well-defined protocols that, when combined, enable a well – understood method of performing store – and forwarding communications. Some of the key capabilities of Bundle Protocol include [5]: Custody Transfer – the ability for a bundle node to take full responsibility for a bundle reaching its final destination.

- The ability for implementations to cope with intermittent connectivity if required.
- Ability for implementations to cope with long propagation delays if required.
- Ability to take advantage of scheduled, predicted, & opportunistic connectivity (in addition to continuous connectivity).

The basic idea is that, each packet transmitted is called a 'bundle' and contains all of the signalling as well as the data required to transit the transport layer which is referred to as the bundle convergence layer, the DTN nodes are identified by the End Point Identifiers (EPI) , which are the bundling equivalent addresses. The bundles are routed in a store and forward manner between participating nodes over varied network transport technologies (including both IP and non-IP based transports).

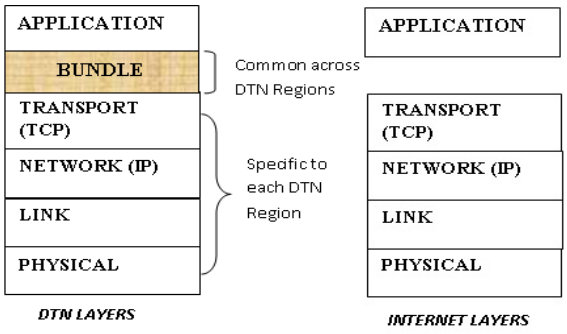

Fig 3: TCP/IP Layer and DTN Layer

The Licklider Transmission Protocol (LTP) is a point-to-point protocol designed to be a potential convergence layer to support the bundle protocol, though it can also be used in other contexts. It is primarily designed for the high-latency case of deep space communication to be usable as a convergence layer for the bundle protocol. But it can also be used above traditional connection-less transport layer like UDP in terrestrial context; including sensor networks using data mules [6].

VI. APPLICATIONS OF DELAY – DISRUPTION TOLERANT NETWORKS:

The Delay – Disruption Tolerant Networks is an active research area and has been initially developed for Deep Space Communication (Inter – Planetary Internet), however the Delay Tolerant Networks has wide spectrum of advantages and applications across terrestrial scenarios ranging from providing connectivity across all environments, Underwater/Acoustic networking, Tactical Military applications and the like.

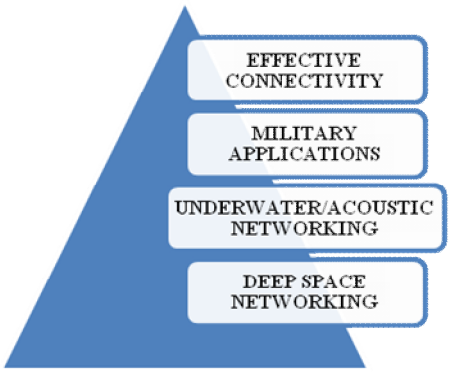

Fig 4: DTN Core Applications

i. DEEP SPACE NETWORKING:

The DINET I, known as Deep Impact Network is an experimental validation of Inter – Planetary Networks, which is the NASA's implementation of Delay – Tolerant Networks. NASA (National Aeronautics & Space Administration) has successfully tested the first deep space communication network model using the DTN by transmitting around 200 space images (approx 14 MB) to and from a space craft known as EPOXI – uploaded with DTN software (functioned as a DTN router,) located more than 32 million kilometres from earth. The DTN prioritization has ensured that all high priority images were successfully delivered and no data loss or corruption found anywhere in the network. DINET II is designed to develop and validate additional DTN functionality like extended priority system, contact graph routing management and so on [7]. Along with the European Space Agency, NASA has successfully used DTN protocols to control and drive a small LEGO robot (car) at European Space Operation Centre located at Darmstadt, Germany from the International Space Station (ISS). The Multi – Purpose End – to – End Robotic Operation Network (METERON) is an application of DTN which aims at simulating selected future human exploration scenarios including immersive remote control of a robot by an astronaut in orbit around a target object (such as Mars or Moon) [8].

ii. TACTICAL MILITARY APPLICATIONS:

With gradual deepening and development of modern military warfare towards Network Centric Warfare (NCW), the performance of Networks and Protocols will play a significant role. The custom network protocols based on end – to – end connectivity is not suited for military communication networks, which is a long/variable delay with high error rates and greatly heterogeneous. Realisation of a robust, intelligent and integrated communication and careful consideration of types of assets that have to be connected will form a solid foundation for Network Centric Warfare. The vast repertoire of military assets include Ground Troops, Armoured – Non armoured vehicles, Naval Platforms, Airborne units, along with Command & Control and Intelligence , Surveillance, Reconnaissance assets that may be fixed or mobile. Moreover the tactical environment is extremely harsh and with marching troops to supersonic tactical aircraft, the huge extent of mobility gap and heterogeneous nature introduces more challenges in traditional protocol design. These conditions results in Intermittent Connectivity with wide ranging communication delays.

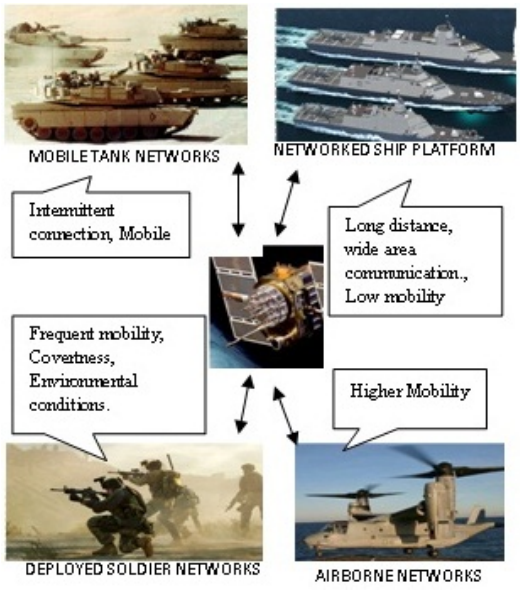

Fig 5: Challenges Faced In Tactical Military Operation.

DTN overcomes the problems associated with intermittent connectivity, long delays and high error rates using Store and Forward Message switching, caching of in – transit data packets, and message ferrying and network connection state hibernation for subsequent reactivation. Studies conducted at Intel & Berkley (Demmer 2004) have indicated significant improvement when DTN techniques are employed.

iii. UNDERWATER/ACOUSTIC NETWORKING:

The underwater acoustic networks are generally formed by acoustically connected ocean – bottom Sensors, autonomous underwater vehicles & surface stations which provide links to on – shore control centre. Underwater Acoustic network is growing rapidly due to its advantages in disaster Prevention, Harbour Portal, Underwater Robotics, Tactical under sea Surveillance, oil – gas pipelines monitoring, Offshore explorations, Pollution monitoring & oceanographic data collection, Salinity Monitoring. But the challenges include slow propagation of acoustic waves, limited bandwidth and very high delays. Multiple unmanned or autonomous underwater vehicles (UUVs, AUVs), equipped with underwater sensors, will also find its application in exploration of natural undersea resources and gathering of scientific data in collaborative monitoring missions. To make these applications viable, there is a need to enable underwater communications among underwater devices [9]. Approaches like Delay Tolerant Network may be a better match to many underwater networks by avoiding end – to – end retransmission & supporting very sparse & often disconnected networks [10].

iv. SMARTPHONE APPLICATION:

The Delay Tolerant Network Approach can be implemented in the Android platform to provide connectivity in environments that lack Efficient Network Infrastructures. The implementation of DTN services and protocol stack on the Android platform is known as “Bytewalla” which allows the use of android phones for the physical transport of data between network nodes in areas where there are no other links available or when the existing links are highly intermittent.

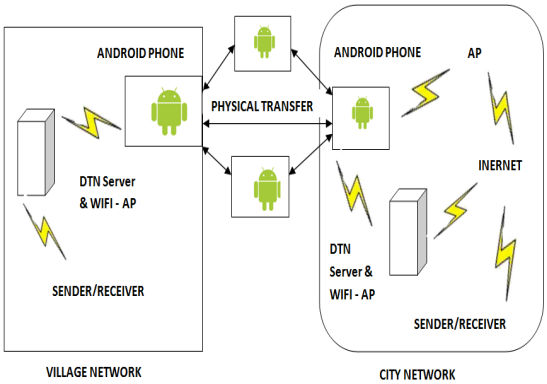

Fig 6: Bytewalla Architecture

The Bytewalla network architecture consists of two networks which can be deployed to interoperate from two separate remote locations [11].

VII. CONCLUSION:

The DTN Architecture is primarily designed to effectively operate as an overlay on top of regional or complex broken networks or as an Inter Planetary Internet. The Delay Tolerant Network can trounce problems that are branded with extensive – Delays, Asymmetric Data Rates, discontinuous/flashing Connectivity, High fault Rates due to severe environmental conditions, distance critical scenarios encountered in Space communication at Inter – Planetary scale competently and optimistically when compared with the traditional Internet suite. With increasing efficiency and varied effective applications across core domains like Military, Terrestrial and Network connectivity, the DTN would form the future of Network Connectivity and Communication.

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