Routing Enhancement Specific to Mobile Environment Using DTN

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Abstract—**A communications network that withstands long delays or outages and is capable of storing packets temporarily stationed in intermediate nodes, until an end-to-end route is re-established or regenerated is known as a delay tolerant network or in short DTN. This paper aims to consolidate general & basic aspects relating to information needs to efficiently execute DTN routing. We start by presenting the evolution of some routing protocols, spotting few routing schemes relevant to us, discuss their groups and classifications, their operating network environment, and through critical study and observation, to identify specific parameters that are common across relevant schemes associated with routing that helps to bring out the advantage and disadvantage associated with them in an attempt to establishing some possible future extensions-of-the-existing through consolidation - accomplished by capturing, organizing and showcasing the same in metrics and proposing new schemes as well. This leads us to identify specific schemes such as controlled replication and techniques that will help us to exploit the *delay* and utilize the time judiciously to improve the overall efficiency of information exchange in a DTN network. The essence of this study being; to utilize efficiently the temporal period (delay) by opportunistically establishing connectivity - in a strategic manner, to help exchange information across by locally distributed resources, thus making optimal use of available network resources and enhancing the efficiency of information exchange.**

Index Terms—**Forwarding, replication, single-copy, multiple-copy, relay, delivery ratio, delay, throughput, local resource, Routing techniques, routing efficiencies, protocol**

I. Introduction

With explosive growth in mobility driven by increasing diversity in the number and breadth of tablets, smart phones and media expected to continue, the burden on IT continues to increase. The network has to converge into a single platform that simplifies the user experience, automates tasks for IT, and enables the expansion and diversification of services. Delay tolerant network is kind of opportunistic network where most of the time there does not exist end to end path from source to destination. Here, the performance of network may vary significantly, depending on how the mobile nodes move, how dense the nodes populations are, and how far apart the sender and the receiver are. Delivery latency may vary from a few minutes to hours to days, and a significant fraction of the messages may not be delivered at all [1].

The basic idea behind DTN network is that endpoints connectivity is not constant – for other obvious reasons as well. But, as a specific situation, in order to facilitate data transfer, DTN uses "*store-and-forward*" approach across routers that are more disruption-tolerant (delay) compared to TCP/IP, particularly in case of network-routing. DTNs are frequently used in disaster relief missions, peace-keeping missions, and in vehicular networks or most data exchanges, this additional delay is acceptable and could even be an advantage as well. The reason for this is the fact that nodes are actually silent processors that not only help channel data packets ("Throw boxes [2] or "Data mule [3]" or relay nodes) to destination but can also provide higher bandwidth – through judicious use and processing. Higher bandwidth attribute of the node will eventually contribute in reducing the number of hops.

Several proposals for efficient routing mechanisms have been devised [3,4,5,6,7], claiming superiority based upon experimental and software simulated data results. In this paper, we aim to inspect what are the different techniques available [4,5]. Techniques & strategies that recognize: who, whom, & when [8] for routing along with classification chart and criteria for classification. Further, it is attempted to analyze and ink controlled replication technique and show case assumption, strategy, node type, movement pattern and future extensions. This brings important generic routing aspect in DTN environment on surface and future actions.

In Section-II, we address and discuss general aspects relating to DTN routing, types, some classification criteria & chart, followed by Section-III discusses about controlled replication technique and summarize evolution of protocols based on this; Section-IV concludes by presenting an outcomes of studies in routing & future work.

II. Routing in DTN

Routing aims in finding a path (optimal/suboptimal) to destination. In opportunistic and or delay tolerant environment/application; it means optimization of resources achieving network efficiencies and economies in terms of battery life and network resources usage and better packet deliveries. Depending on the application using the DTN, it can be useful to drop packets and free buffers quite early paving way to newly sent packets, and a good chance to deliver in time, while, on the other hand, it may be important to deliver as many packets as possible, no matter how long it lasts.

Routing in opportunistic networks is broadly classify

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based on number of copies distributed into network namely single copy (forwarding), Multi copy (replication / flooding) and fixed number of copies (controlled replication / quota based replication/ hybrid scheme.) Table-1 shows the short comparative giving an idea about basic schemes and narrates the details in brief.

- **Single copy**: There is only a single custodian for each message. When the current custodian forwards the copy to an appropriate next hop, this becomes message new custodian, and so on and so forth until message reaches its destination.
- **Replication:** Source nodes spread copies of message to **nodes** in contact & not containing same copy of message. each node/relay spreads same copy of messages throughout the network until messages reaches to destination.
- **Controlled Replication:** Fixed number of redundant copies is spread **into** network. This helps in achieving the better delivery ratio, few transmissions and lower delivery delays in presence of scarce network resources. Table -1 [13]

TABLE 1. COMPARATIVE OF MESSAGE COPY TECHNIQUES

Parameters	Single copy	Multiple Copy	ontrolled Copy
Reference protocol cited for comparative	Direct delivery [9] [11]	Epidemic [8]	Binary pray and Wait [10]
Message copies	Single	Many	x number
No. of transmission	Lower	Many	ower than multiple copy
Delivery delays	Higher	Lower	ower than ngle copy
Delivery ratio	Lower	Higher	etter than ngle copy
Contention	No	Higher	Lower
Network resource wastage	No	Higher	ower than ulti copy

Further classification are based on following criteria :

- **Stateless:** No further (past or future) location or contact data is needed to make the forwarding decisions.
- **History-based:** These algorithms use past to find an efficient route to the destination node. Logged data can be a history of recent encounters with other contacts as well as for example contact-time, contact-frequency, and contact-time-location tuples.
- **Movement-based**: Some routing ideas are based on feeding the probability function to determine forwarding decisions with movement and velocity data.
- **Scheduling-based:** Approaches based on scheduling are mainly of supportive nature.
- **Beacons-less:** Most routing protocols require knowledge of a node's neighbors to make their routing decisions. This information is generally gathered by the use of beacons, messages broadcasted regularly that will be heard by all nodes within communication distance.
- **Position-based:** These algorithms look the position of the destination nodes using a Location Server and add this position in the packet header. Nodes that receive the packet apply a forwarding strategy to retransmit the packet. Each node stores a node ID, the direction and distance to the node, as well as an age time. Forwarding Strategies decide towards which node or area the packet forwarded.
- **Opportunistic:** In an opportunistic network, each node decides locally to which next hop the packet will be forwarded. This next-hop may decide to store the packet until a new opportunity [12] to forward the packet appears.
- **Oracle based:** Algorithms are classified based on their source of routing knowledge.
- **Knowledge oracle:** DTN routing problem has many input variables such as dynamic topology characteristics and traffic demand. Complete knowledge of these variables facilitates the computation of optimal routes. These oracles are notational elements used to encapsulate particular knowledge about the network required by different algorithms.

Figure-1 shows the DTN uncast routing classification chart with example protocol for each of categories and subcategories. Further, it shows the criteria based on which various schemes are evolved. Direct delivery, epidemic, spray and wait are some of generalize techniques which may be applied to all the DTN applications where in, social based, cloud, scheduling are specific to applications. Executive summary for some of routing techniques/schemes studied along with parameter details like mobility models, application environment and protocols captured and showcased in Table: 2.

Mobility model based on simulation depicts the movement patterns of mobile nodes; data utilized for the purpose of software based simulation and analysis have been used by other researchers earlier and fairly predicts & approximate the real situations existing while evaluating the model Functions - protocol. Moreover, parameter-item relating to application environment expresses the limitations of protocol mentioned by the author(s) [14] in their reported and published paper/s.

As detailed under table-2, several schemes can be applied to general mobile network, followed by some assumptions and approximations that steer towards a near optimal routing solution and a network topology; to be evolved.

TABLE 2. SUMMARY OF DTN ROUTING PROTOCOLS

Sr. No	Protocol	Main Strategy	Mobility Model for simulation	Applicable environment
1	Direct delivery	Source waits until it comes into contact	Mobility not evolved.	Info station Architecture
2	First contact	Use any available contact. No oracle used.	Remote village , city bus network scenario	General delay tolerant network
3	Message Ferries	A set of particular nodes called message ferries take charge of forwarding	Message ferry follows the rectangle route and other nodes Adopt random waypoint, limited random waypoint and area-based model	Ferries move in proactive manner for communication
4	Throwboxes	Deploy static relay devices based on different level of information to enhance data transfer capacity	Random waypoint and UMass model	Static nodes are needed for message exchange
5	Seek and Focus	Make use of randomized forwarding and utility based routing	Random Waypoint model and Community based Mobility	General mobile network
6	MobySpace	Find the node with the similar mobility pattern as that of destination to forward	Power-law based mobility pattern	Assume the mobility pattern of destination is known
7	Epidemic	Flood message	Random waypoint model	General mobile network
8	PROPHET	Select the relay nodes by Predicting the delivery probability	Random Waypoint model and Community model	General mobile network
9	Spray and Wait	Take advantage of limited number of nodes to flood message	Random waypoint model and Community based Mobility	prefers the network with sufficiently mobile nodes
10	Spray and Focus	Take advantage of limited number of nodes to flood message	Random waypoint model and Community based Mobility	prefers the network with localized nodes
11	Island Hopping	Rely on the cluster to forward message	Random walk with different exponentially distributed pause and move time	Rely on the presence of stable topology of clusters
12	Simple Replication	Source of the message is permitted to transmit/sends multiple copies, while the relay nodes are allowed to send /forward only to the destination	Real traced based mobility Zebra net	Wildlife monitoring
13	History based replication	Source creates "*r*" identical copies of a message, which are then delivered to the "best" *r* nodes, where quality is determined by history.	Real traces using Zebra net	Wildlife monitoring
14	Erasure coding	*kr* fragments totaling *r* times the message size are generated and sent to the first *kr* intermediate relays.	Real traces using Zebra net	Generic routing scheme
15	Estimation based erasure coding	Two communicating intermediate nodes exchange data until the number of fragments for a given destination is proportional to the nodes' probability of meeting the destination	Restrict random way point model	Generic routing scheme
16	MV Routing	Find peer having maximum probability of visiting the region of destination	Synthetic traces of peer movements in geographic area.	Vehicular area network
17	Maxprop	forward the message to any device in the network having maximum probability of delivering the message to destination	Map based mobility	Vehicular area network
18	Earliest delivery	Compute the path using modified Dijikstra algorithm	Not available	Unrealistic knowledge of future.

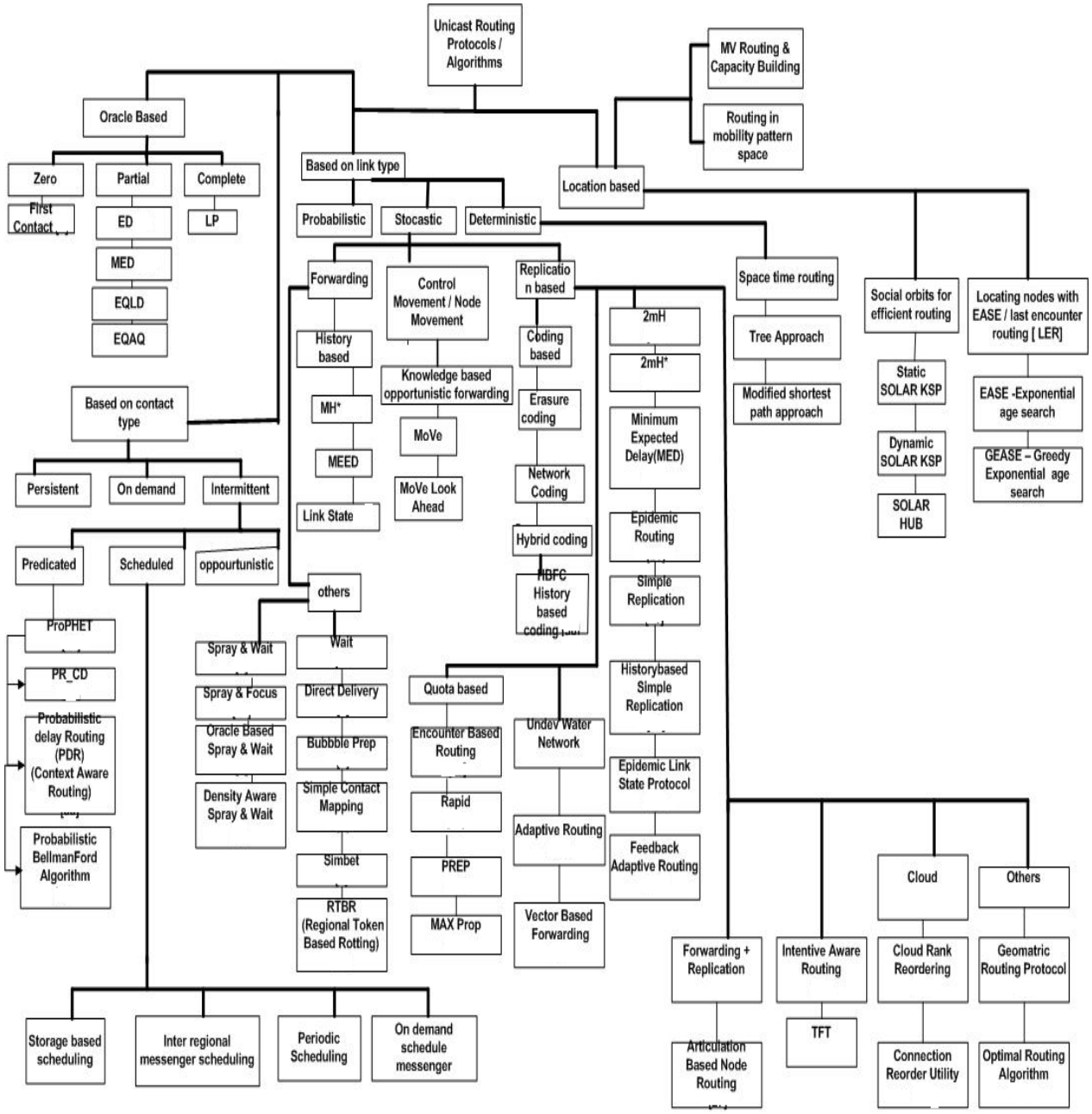

Fig. 1 DTN Uncast routing classification chart

III. Controlled Copy/Replication Schemes

Thrasyvoulos Spyropoulos et.al. Has described controlled replication as "When a new message is generated at a source node, this node also creates L "forwarding tokens" for this message. A forwarding token implies that the node that owns it can spawn and forward an additional copy of the given message". During the spraying phase, messages get forwarded according to the following rules: if a node (either the source or a relay), carrying a message copy and f > 1 forwarding tokens for this message, encounters a node with no copy of the message1, it spawns and forwards a copy of that message to the second node; it also hands over l(f) tokens to that node (l(f) [1; f-1]) and keeps the rest c ¡ l(f) for itself ("Spray" phase);

When a node has a message copy and f = 1 forwarding tokens for this message, then it can only forward this message to the destination itself ("Wait" phase).

let's look at various controlled replication schemes from its evolution to trends (latest) comprising broadly an network operating environment, algorithm, spraying schemes, message and node distribution, mobility model, used, assumptions, advantages and possible extensions as shown in Table-3.

TABLE 3. EVOLUTION OF VARIOUS CONTROLLED REPLICATION ROUTING PROTOCOLS

Algorithm	Assumptions	Spraying strategy	Node Movement	Node Type	Mobility Model	Advantages	Future extension
Source Spray & Wait [5]	No contention, Infinite bandwidth, Infinite buffer	Source node forwards L copies of same message to L first L distinct nodes	I.I.D.	Homogeneous	Stochastic model	Fewer transmission than epidemic, low contention under high traffic, scalable, requires little knowledge about network	Needs to investigate the performance in presence of real trace based mobility models, Optimal spraying strategy
Binary Spray & Wait [5]	No contention, Infinite bandwidth, Infinite buffer	Random forwarding in spray phase (Greedy way)	I.I.D.	Homogeneous	Stochastic model	Fewer transmission than epidemic, low contention under high traffic, scalable, requires little knowledge about network	Needs to investigate the performance in presence of real trace based mobility models & node distribution, Explore spray strategies rather using performing random spray
Spray & Focus[15]	Infinite Buffer, Infinite Bandwidth	Random forwarding in spray phase and utility based direct transmission in wait phase	I.I.D.	Heterogeneous	Stochastic model	Improves the performance by 20x than spray & wait	Finding optimal distribution strategy
Spray & Wait with PROPHET[3] [16]	-	Binary with avg. delivery predictability metric	Not I.I.D.	Heterogeneous	Map based mobility	Shorter delay with small value of message copy L	Buffer management policies for history and messages.
Fuzzy Spray & Wait [17]	Finite storage and bandwidth, Pragmatic assumption	Fuzzy Based on FTC count	I.I.D.	Homogeneous	Stochastic	Less sensitive to chosen parameters(fuzzy membership function)	Needs to investigate the performance in real trace based mobility models with heterogeneous nodes
Density aware spray and wait [18]	Contention free access, Infinite bandwidth, Infinite storage	Accordion phenomenon (slinky effect)	Not I.I.D.	Heterogeneous	Roller net , trace based	Investigate for good predictors for anticipating changes in mobility patterns, Study and use social communities in the roller tour. Detect the social grouping in decentralized fashion and that can be used to make good routing decisions.	
Dynamic Spray & Wait [19]	Finite buffer	Ratios of QoN.	Not I.I.D.	Heterogeneous	Map based mobility	Adapts to real dynamic network conditions, enhances delivery utility	Needs to make more energy efficient

IV. SUMMARY & CONCLUSION

This paper introduces the basics of routing, its objectives & purpose, types, classification groups and collectively discusses 18 different routing techniques; leading to identification of critical & explicit parameters of each of the technique studied.

Mobility model based on simulation depicts the movement patterns of mobile nodes; data utilized for the purpose of software based simulation and analysis have been used by other researchers earlier and predict by simulation, with fair accuracy the real situations existing while evaluating the model functions - protocol. Moreover, parameter-items relating to application environment express the limitations of protocol as mentioned by the author(s) under respective titles in this paper. As detailed under table-1, several schemes can be applied to general mobile network, followed by some assumptions and approximations that steer towards a near optimal routing solution and a possible optimal network topology - to be evolved in due course.

Further, the essence of the 18 techniques studied along with quantifiable parameter and details like mobility models, application environment and protocols etc., is captured and showcased under table-1.

REFERENCES

[1] Sushant Jain, Kevin Fall, and Rabin Patra. Routing in a delay tolerant network. In SIGCOMM '04: Proceedings of the 2004 conference on Applications, technologies, architectures, and protocols for computer communications, pages 145{158, New York, NY, USA, 2004. ACM.

[2] Jea D., Somasundara A. A, Srivastava M. B. Multiple Controlled Mobile Elements (Data Mules) for Data Collection in Sensor Networks. IEEE/ACM International Conference on Distributed Computing in Sensor Systems (DCOSS) June 2005.

[3] A. Lindgren, A. Doria, O. Schelen. Probabilistic routing in intermittently connected networks,. SIGMOBILE Mobile Computing and Communications Review. Vol. 7,2003

[4] T. Spyropoulos, K. Psounis, C. S. Raghavendra. Efficient routing in intermittently connected mobile networks: The single-copy case. , IEEE/ACM Trans. on Networking. Vol. 16, 2008

[5] T. Spyropoulos, K. Psounis, and C. S. Raghavendra. Efficient routing in intermittently connected mobile networks:: The multiple-copy case.. IEEE/ACM Trans. on Networking. Vol. 16, 2008

[6] A. Vahdat, D. Becker. Epidemic routing for partially connected ad hoc networks Duke University: s.n., 2000. Technical Report CS-200006.

[7] J. Burgess, B. Gallagher, D. Jensen,B. Levine. Barcelona, Spain: Maxprop: Routing for vehicle-based disruption tolerant networking. s.n., IEEE Infocom, April 2006.

[8] S. Jain, K. Fall, R. Patra. Routing in a Delay Tolerant Network.. Proc. ACM SIGCOMM. pp. 145–158, 2004.

[9] J. Widmer J.-Y. Le Boudec: Network coding for efficient communication in extreme networks ACM SIGCOMM Workshop on Delay-Tolerant Networking (WDTN'05). - August 2005. - pp. 284–291

[10] Thrasyvoulos Spyropoulos Konstantinos Psounis,Cauligi S. Raghavendra : Spray and wait: an efficient routing scheme for intermittently connected mobile networks SIGCOMM. - USC : ACM, 2005
[11] R. H. Frenkiel B. R. Badrinath, J. Borres, R. D. Yates:The infostations challenge: balancing cost and ubiquity in delivering wireless data IEEE Personal Communications. - 2000. - Vols. 7, No. 2. - pp. 66–71.
[12] M. Shin, S. Hong, and I. Rhee. DTN Routing Strategies using Optimal Search Patterns. CHANTS'08.
[13] Yogeshwar Kosta P, Hemal Shah."Evolution of various controlled replication routing schemes for opportunistic networks"AUC 2010, accepted & to be published by Springer AUC 2.0 conference proceedings in CCIS series
[14] Yogeshwar Kosta P, Hemal Shah"Evolution of Routing techniques, routing protocols and routing efficiencies for Delay Tolerant Network" IJCA Special Issue on MANETs (1):46–53, 2010. Published by Foundation of Computer Science.
[15] Thrasyvoulos, S., Konstantinos, P., Cauligi, S. Raghavendra: Spray and Focus: Efficient Mobility-Assisted Routing for Heterogeneous and Correlated Mobility Pervasive Computing and Communications Workshops, 2007. PerCom Workshops '07. Fifth Annual IEEE International Conference. : IEEE, March 2007. - pp. 79 – 85
[16] Jingfeng Xue Xiumei Fan, Yuanda Cao, Ji Fang, Jiansheng Li: Spray and Wait Routing Based on Average Delivery Probability in Delay Tolerant International Conference on Networks Security, Wireless Communications and Trusted Computing. : IEEE Computer Society, 2009.
[17] Akadet Mathurapoj Chotipat Pornavalai, Goutam Chakraborty: Fuzzy Spray: Efficient Routing in Delay Tolerant Ad-hoc network based on Fuzzy Decision Mechanism FUZZ-IEEE. - Korea: IEEE, 2009.
[18] Pierre-Ugo Tournoux J´er´emie Leguay, Farid Benbadis, Vania Conan, Marcelo Dias de Amorim, and John Whitbeck: The Accordion Phenomenon: Analysis, Characterization, and Impact on DTN Routing IEEE INFOCOM 2009: IEEE Communications Society.
[19] Guizhu Wang Bingting Wang, Yongzhi Gao :Dynamic Spray and Wait Routing algorithm with Quality of Node in DelayTolerant Network International Conference on Communications and Mobile Computing. : IEEE, 2010.

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