www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume - 3 Issue - 8 August, 2014 Page No. 7699-7713

Code controlling in DTN's for progressive packet arrival dynamically

Uma Upadhya, Dr. Shubhangi D.C Rekha B Venkatapur

4th Semester Mtech CSE, VTU PG center Gulbarga, Karnataka, India.
uma03upadhya@gmail.com

, HOD and professor of CSE, VTU PG center Gulbarga, Karnataka, India.
shubhangidc@yahoo.co.in

, HOD and professor of CSE, KSIT college, Bangalore, Karnataka, India.
vb_rekha2000@yahoo.co.in

ABSTRACT

In Delay Tolerant Networks (DTNs) the core challenge is to cope with lack of persistent connectivity and yet be able to deliver messages from source to destination. In particular, routing schemes that leverage relays' memory and mobility are a customary solution in order to improve message delivery delay. So when large files need to be transferred from source to destination, not all packets may be available at the source prior to the first transmission. This motivates us to study general packet arrivals at the source, derive performance analysis of replication based routing policies and study their optimization under two hop routing. Here we determine the conditions for optimality in terms of probability of successful delivery and mean delay and we devise optimal policies, so-called piecewise-threshold policies. We account for linear block-codes and rate less random linear coding to efficiently generate redundancy, as well as for an energy constraint in the optimization.

2. Introduction

DTN

Delay Tolerant Networks (DTNs), also called as intermittently connected mobile networks, are wireless networks in which a fully connected path from source to destination is unlikely to exist. However, effective forwarding based on a limited knowledge of contact behavior of nodes is challenging. When large files need to be transferred from source to destination make all the packets available at the source and transfer the file as small packets. Study of the packets arrival at source and analysis of their performance is done. It is considered that the linear blocks and rateless linear coding to generate redundancy and also for energy constraint . Scheduling the large file into small packets and delivering through multipath to destination, for this we use optimal user centric allocation and scheduling the packets in the receiver side.

Delay or Disruption Tolerant Networks (DTNs) are characterized by long delays and intermittent connectivity. Moreover, they may have power constraints, low and asymmetric bandwidth, and high bit-error rates. .

Model of DTN

Consider a network that contains N + 1 mobile nodes. Two nodes are able to communicate when they come within reciprocal radio range and communications are bidirectional .Assume that the duration of such contacts is sufficient to exchange all frames: this allows to consider nodes meeting times only, i.e., time instants when a pair of not connected nodes falls within reciprocal radio range. Times between contacts of pairs of nodes are exponentially distributed with given inter-meeting intensity. A file contains K frames. The source of the file receives the frames at some times $t1 \leq t2 \leq ... \leq tK$.ti are called the arrival times. The transmitted file is relevant during some time τ. By that it is meant that all frames should arrive at the destination by time t1+τ. Do not assume any feedback that allows the source or other mobiles to know whether the file has made it successfully to the destination within time τ.If at time t the source encounters a mobile which does not have any frame, it gives it frame i with probability ui(t). Consider two-hop routing In this two concept are used, overwrite case and non-overwriting case .In the existing concept non-overwriting case are highly efficient but overwriting case without constraints are not efficient, so in this work it uses rateless code and block code for removing the overwriting case due to the transmission of packet . Rateless code and block code is used to share the information sequence to the receiver without data loss, overwriting and delay. In this work due to the data transmission the multi path can be create using optimal user centric algorithm in the source side. Using the multi path the data can split into packet and assign packet to each node due to the transmission then packet are schedule using decentralized routing process based on the integer linear programming in the receiver side In the scheduling packet the packet can schedule and receive to the client side. Erasure coding technique to increase the reliability and to further decrease the cost of routing are used. For a given desired delivery rate and deadline for delivery, it is found that optimum parameters to obtain the smallest cost both in single period and two period erasure coding based routing. Also analyze the effects of message distribution algorithms on the cost of routing both in replication based (i.e. spray and wait) and erasure coding based algorithms. Analyze real

DTN traces and detect the correlations between the movements of different nodes using a new metric called conditional intermeeting time. Then use the correlations between the meetings of a node with other nodes for making the existing single-copy based routing algorithms more cost efficient.

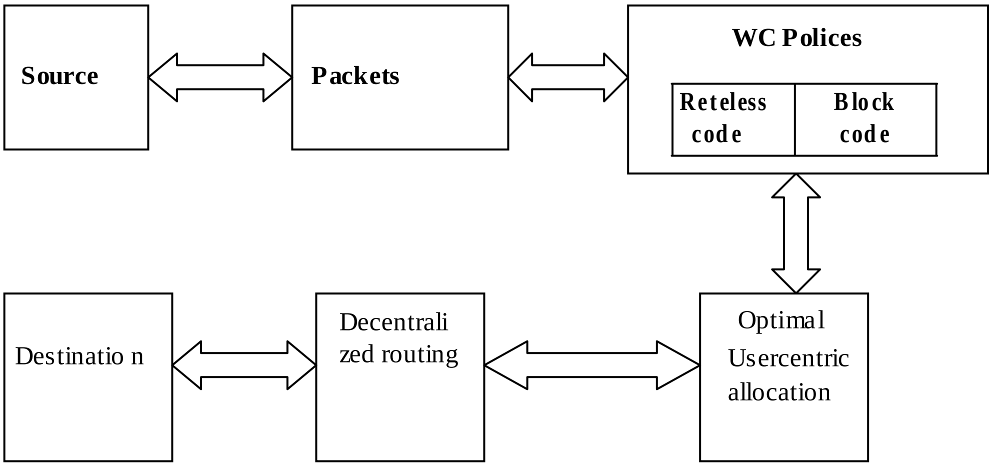

Fig. 1.2: DTN model

3 Objective

The main objective of the paper is to derive performance analysis of replication based routing policies and study their optimization under two-hop routing. The conditions for optimality in terms of probability of successful delivery and mean delay are determined and devise optimal policies, so-called piecewise-threshold policies.

4 Statement of Problem

For work-conserving policies (i.e., the source sends systematically before stopping completely), derive the conditions for optimality in terms of probability of successful delivery and mean delay.

- In the case of non-overwriting, prove that the best policies, in terms of delivery probability, are piecewise threshold. For the overwriting case, work-conserving policies are the best without energy constraint, but are outperformed by piecewise- threshold policies when there is an energy constraint.
- Extend the above analysis to the case where copies are coded packets, generated both with linear block codes and rate less coding. Also account for an energy constraint in the optimization.
- Illustrate numerically, in the non-overwriting case, the higher efficiency of piecewise- threshold policies compared with work-conserving policies by developing a heuristic optimization of the thresholds for all flavors of coding considered. As well,

in the overwriting case, we show that work-conserving policies are the best without any energy constraint.

5 Review of Literature

[1] E. Altman, F. De Pellegrini, and L. Sassatelli **"Dynamic control of coding in delay tolerant networks"**. The authors study replication mechanisms that include Reed-Solomon type codes as well as network coding in order to improve the probability of successful delivery within a given time limit. They propose an analytical approach to compute these and study the effect of coding on the performance of the network while optimizing parameters that govern routing. The memory of a DTN node is assumed to be limited to the size of a single

frame. They study adding coding in order to improve the storage efficiency. They consider Reed-Solomon type codes as well as network coding.

[2] E. Altman and F. De Pellegrini **"Forward correction and Fountain codes in delay tolerant networks".** Delay-tolerant ad hoc networks leverage the mobility of relay nodes to compensate for lack of permanent connectivity and thus enable communication between nodes that are out of range of each other. To decrease delivery delay, the information to be delivered is replicated in the network. Their objective in this paper is to study a class of replication mechanisms that include coding in order to improve the probability of successful delivery within a given time limit. They propose an analytical approach that allows to quantify tradeoffs between resources and performance measures (energy and delay). They study the effect of coding on the performance of the network while optimizing parameters that govern routing. Their results, based on fluid approximations, are compared to simulations that validate the model. A native approach is to forward a file to the destination is by epidemic routing in which any mobile that has the message keeps on relaying it to any other mobile that falls within its radio range. This would minimize the delivery delay at the cost of inefficient use of network resources (e.g. in terms of the energy used for flooding the network). The need

for more efficient use of network resources motivated the use of less costly forwarding schemes such as the two-hops routing protocols. In two-hops routing the source transmits copies of its message to all mobiles it encounters; relays transmit the message only if they come in contact with the destination.

[3] T. Spyropoulos, K. Psounis, and C. Raghavendra **"Efficient routing in intermittently connected mobile networks: the multi-copy case".** Intermittently connected mobile networks are wireless networks where most of the time there does not exist a complete path from the source to the destination. There are many real networks that follow this model, for example, wildlife tracking sensor networks, military networks, vehicular ad hoc networks, etc.

In this context, conventional routing schemes fail, because they try to establish complete end-to-end paths, before any data is sent.

To deal with such networks researchers have suggested to use flooding-based routing schemes. While flooding-based schemes have a high probability of delivery, they waste a lot of energy and suffer from severe contention which can significantly degrade their performance. Furthermore, proposed efforts to reduce the overhead of flooding-based schemes have often been plagued by large delays. With this in mind, they introduce a new family routing schemes that "spray" a few message copies into the network, and then route each copy independently towards the destination. They show that, if carefully designed, spray routing not only performs significantly fewer transmissions per message, but also has lower average delivery delays than existing schemes; furthermore, it is highly scalable and retains good performance under a large range of scenarios.

Finally, they use their theoretical framework proposed in their 2004 paper to analyze the performance of spray routing. They also use this theory to show how to choose the number of copies to be sprayed and how to optimally distribute these copies to relays.

[4] E. Altman, T. Bas¸ar, and F. De Pellegrini**, "Optimal monotone forwarding policies in delay tolerant mobile ad-hoc networks".** In this paper they describe a framework for the optimal control of delay tolerant mobile ad hoc networks where multiple classes of nodes co-exist. They specialize the description of the energy-delay tradeoffs as an optimization problem based on a fluid approximation. They then adopt two product forms to model message diffusion and show that optimal controls are of bang-bang type. Under this general framework, they analyze some specific cases of interest for applications. In the paper, they study the problem of optimal control of routing. To this respect, in view of the use of battery operated mobile terminals, a mobile DTN depends on its overall energy budget. The energy budget has to accommodate the cost of energy expended on message forwarding. Intuitively, the higher the number of message copies, the smaller the message delay. This gain comes at a price of higher energy expenditure. More precisely, a finite energy cost accrues every time a message is transmitted and received. In the following it is assumed that the energy expenditure is linear in the number of released copies; this is a viable approximation especially for sparse networks where the impact of interference and collisions can be neglected.

[6] J. Nonnenmacher, E. Biersack, and D. Towsley **"Parity-based loss recovery for reliable multicast transmission".** The authors investigate how forward error correction (FEC) can be combined with automatic repeat request (ARQ) to achieve scalable reliable multicast transmission. They consider the two scenarios where FEC is introduced as a transparent layer underneath a reliable multicast layer that uses ARQ, and where FEC and ARQ are both integrated into a single layer that uses the retransmission of parity data to recover from the loss of original data packets. To evaluate the performance improvements due to FEC, they consider different loss rates and different types of loss behavior (spatially or temporally correlated loss, homogeneous or heterogeneous loss) for up to 10^6 receivers. Their results show that introducing FEC as a transparent layer below ARQ can improve multicast transmission efficiency and scalability. However, there are substantial additional improvements when FEC and ARQ are integrated.

FEC by itself cannot provide full reliability. Therefore, when coupled with ARQ, FEC can produce inherently scalable reliable multicast transport protocols. If introduced as a separate layer beneath the ARQ layer, it has the effect of substantially reducing the packet loss probability and, thus, reducing the number of packet retransmissions and network bandwidth requirements. If integrated with ARQ, then FEC introduces the following:

- A *single parity packet* can repair the loss of *different data packets at different receivers.*
- Using parity packets for loss repair, the sender needs to know only the maximum number of packets lost by any receiver but not their sequence numbers. Feedback from a single receiver is reduced to a single number for a group of packets

[8] Yong Wang, Sushant Jain†, Margaret Martonosi, Kevin Fall On "**Erasure-Coding Based Routing for Opportunistic Networks"** Routing in Delay Tolerant Networks (DTN) with unpredictable node mobility is a challenging problem because disconnections are prevalent and lack of knowledge about network dynamics hinders good decision making. Current approaches are primarily based on redundant transmissions. They have either high overhead due to excessive transmissions or long delays due to the possibility of making wrong choices when forwarding a few redundant copies. In this paper, the authors propose a novel forwarding algorithm based on the idea of erasure codes. Erasure coding allows use of a large number of relays while maintaining a constant overhead, which results in fewer cases of long delays.

They use simulation to compare the routing performance of using erasure codes in DTN with four other categories of forwarding algorithms proposed in the literature. Their simulations are based on a real-world mobility trace collected in a large outdoor wild-life environment. The results show that the erasure-coding based algorithm provides the best worst-case delay performance with a fixed amount of overhead. They also present a simple analytical model to capture the delay characteristics of erasure-coding based forwarding, which provides insights on the potential of their approach.

[9] Jorg Widmer, JeanYves Le Boudec on "**Network Coding for Efficient Communication in Extreme Networks"** Some forms of ad-hoc networks need to operate in extremely performance-challenged environments where end-to-end connectivity is rare. Such environments can be found for example in mechanisms in such networks usually resort to some form of intelligent flooding, as for example in probabilistic routing.

They propose a communication algorithm that significantly reduces the overhead of probabilistic routing algorithms, making it a suitable building block for a delay-tolerant network architecture. Their forwarding scheme is based on network coding. Nodes do not simply forward packets they overhear but may send out information that is coded over the contents of several packets they received. They show by simulation that this algorithm achieves the reliability and robustness of flooding at a small fraction of the overhead.

[10] Yunfeng Lin, Ben Liang, and Baochun Li on "**Performance Modeling of Network Coding in Epidemic Routing"** Epidemic routing has been proposed to reduce the data transmission delay in opportunistic networks, in which data can be either replicated or network coded along the opportunistic multiple paths. In this paper, the authors introduce an analytical framework to study the performance of network coding based epidemic routing, in comparison with replication based epidemic routing. With extensive simulations, they show that their model successfully characterizes these two protocols and demonstrates the superiority of network coding in opportunistic networks when bandwidth and node buffers are limited. They then propose a priority variant of the network coding based protocol, which has the salient feature that the destination can decode a high priority subset of the data much earlier than it can decode any data without the priority scheme. Their analytical results provide insights into how network coding based epidemic routing with priority can reduce the data transmission delay while inducing low overhead.

[12] Robin Groenevelt, Philippe Nain, Ger Koole on **"The Message Delay in Mobile Ad Hoc Networks"** A stochastic model is introduced that accurately models the message delay in mobile ad hoc networks where nodes relay messages and the networks are sparsely populated. The model has only two input parameters:

the number of nodes and the parameter of an exponential distribution which describes the time until two random mobiles come within communication range of one another. Closed-form expressions are obtained for the Laplace-Stieltjes transform of the message delay, defined as the time needed to transfer a message between a source and a destination. From this they derive both a closed-form expression and an asymptotic approximation (as a function of the number of nodes) of the expected message delay. As an additional result, the probability distribution function is obtained for the number of copies of the message at the time the message is delivered. These calculations are carried out for two protocols: the two-hop multicopy and the unrestricted multicopy protocols. It is shown that despite its simplicity, the model accurately predicts the message delay for both relay strategies for a number of mobility models (the random waypoint, random direction and the random walker mobility models).

[13] Xiaolan Zhang, Giovanni Neglia , Jim Kurose , Don Towsley on **"Performance modeling of epidemic routing"** In this paper, authors develop a rigorous, unified framework based on ordinary differential equations (ODEs) to study epidemic routing and its variations. These ODEs can be derived as limits of Markovian models under a natural scaling as the number of nodes increases. While an analytical study of Markovian models is quite complex and numerical solution impractical for large networks, the corresponding ODE models yield closed-form expressions for several performance metrics of interest, and a numerical solution complexity that does not increase with the number of nodes. Using this ODE approach, they investigate how resources such as buffer space and the number of copies made for a packet can be traded for faster delivery, illustrating the differences among various forwarding and recovery schemes considered. They perform model validations through simulation studies. Finally they consider the effect of buffer management by complementing the forwarding models with Markovian and fluid buffer models.

[16] Eitan Altman, Giovanni Neglia, Francesco De Pellegrini, Daniele Miorandi on **"Decentralized Stochastic Control of Delay Tolerant Networks"** This report deals with the optimal stochastic control issues in delay tolerant networks. Authors first derive the structure of optimal 2-hop forwarding policies. In order to be implemented, such policies require the knowledge of some system parameters such as the number of mobiles or the rate of contacts between mobiles, but these could be unknown at system design time or may change over time. To address this problem, they design adaptive policies combining estimation and control that achieve optimal performance in spite of the lack of information. They then study interactions that may occur in the presence of several competing classes of mobiles and formulate this as a cost-coupled stochastic

game. They show that this game has a unique Nash equilibrium where each class adopts the optimal forwarding policy determined for the single class problem.

[19] Desmond S. Lun, Muriel M´edard, Ralf Koetter, and Michelle Effros on **"On Coding for Reliable Communication over Packet Networks"** Authors present a capacity-achieving coding scheme for unicast or multicast over lossy packet networks.
packets formed from random linear combinations of previously received packets.
a link arrive according to a process that has an average rate. Thus, packet losses on a link may exhibit correlation in time or with losses on other links. In the special case of Poisson traffic with i.i.d. losses, they give error exponents that quantify the rate of decay of the probability of error with coding delay. Their analysis of the scheme shows that it is not only capacity- achieving, but that the propagation of packets carrying "innovative" information follows the propagation of jobs through a queueing network, and therefore fluid flow models yield good approximations. They consider networks with both lossy point-to-point and broadcast links, allowing us to model both wireline and wireless packet networks.

[20] Christina Fragouli, Jean-Yves Le Boudec, Jorg Widmer on "**Network Coding: An Instant Primer"** Network coding is a new research area that may have interesting applications in practical networking systems. With network coding, intermediate nodes may send out packets that are linear combinations of previously received information.

There are two main benefits of this approach: potential throughput improvements and
a high degree of robustness. Robustness translates into loss resilience and facilitates the design of simple distributed algorithms that perform well, even if decisions are based only on partial information. This paper is an instant primer on network coding: we explain what network coding does and how it does it. They also discuss the implications of theoretical results on network coding for realistic settings and show how network coding can be used in practice.

In the scheme, intermediate nodes

All encoding and decoding operati

6. Proposed System

This paper focuses on general packet arrivals at the source and two-hop routing. This distinguish two cases: when the source can overwrite its own packets in the relay nodes, and when it cannot. The contributions are fourfold:

- ❖ For work-conserving policies (i.e., the source sends systematically before stopping completely), derive the conditions for optimality in terms of probability of successful delivery and mean delay.
- ❖ In the case of non-overwriting, paper prove that the best policies, in terms of delivery probability, are piecewisethreshold. For the overwriting case, work-

conserving policies are the best without energy constraint, but are outperformed by piecewise- threshold policies when there is an energy constraint.

❖ This extend the above analysis to the case where copies are coded packets, generated both with linear blockcodes and rateless coding. Also account for an energy constraint in the optimization.

❖ This illustrate numerically, in the non-overwriting case, the higher efficiency of piecewise-threshold policies compared with work-conserving policies by developing a heuristic optimization of the thresholds for all flavors of coding considered. As well, in the overwriting case, it shows that work-conserving policies are the best without any energy constraint.

$t \qquad \sum$

Advantages of proposed system/paper:

✓ In DTNs the framework is different since the challenge is to overcome frequent disconnections. The paper propose a technique to erasure code a file and distribute the generated code-blocks over a large number of relays in DTNs, so as to increase the efficiency of DTNs under uncertain mobility patterns.

✓ The performance gain of the coding scheme is compared with simple replication. The benefit of coding is assessed by extensive simulations and for different routing protocols, including two hop routing.

✓ The paper addresses the design of stateless routing protocols based on network coding, under intermittent end-to end connectivity, and the advantage over plain probabilistic routing is proven.

7. Algorithms Used

Algorithm 1: Constructing an optimal WC policy

Step 1 Use $p_t = e_1$ at time $t \in (t_1, t_2)$

Step 2 Use $p_t = e_2$ from time t_2 till s (1,2) = min (S (2, {1,2}), t_3). If s (1,2) < t_3 then switch to $p_t = \frac{1}{2}$ $(e_1 + e_2)$ till time t_3.

Step 3 Define $t_{K+1} = \tau$. Repeat the following for i = 3, …., K:

Step 3.1 Set j = i. Set s (i, j) = t_i

Step 3.2 Use $p = \frac{1}{i+1-j}$ $^{i}_{k}e\ \ k$ t_{i+1}). If j = 1 then end.

Step 3.3 If s (i, j – 1) < t_{i+1} then take j = min (j : j ∈ J (t, {1,…,i})) and go to step 3.2

An algorithm has been proposed that has the property that it generates a policy u which is optimal not just for the given horizon τ but also for any horizon shorter than τ. Yet optimality here is only claimed with respect to work-conserving policies.

Algorithm strives for equalizing the less populated packets at each point in time: it first increases the CCI of the latest arrived packet, trying to increase it to the minimum CCI which was attained over all the packets existing before the last one arrived (step 3.2). If the minimum is reached (at some threshold s), then it next increases the fraction of all packets currently having minimum CCI, seeking now to equalize towards the second smallest CCI,

sharing equally the forwarding probability

switch to p_t = 2 (e_1 + e_2) till time

Step 3

Repeat the

following

for i =

3,…, K –

1: Step 3.1 Set j = i. Set s (i, j) = t_i

1 i ∑ k

t

among all such packets. The process is repeated until the next packet arrives: hence, the same procedure is applied over the novel interval.

Algorithm 2: Rateless coding after tK

Step 1 Use p_t = e_1 at time t ∈ (t_1, t_2).

Step 2 Use p_t = e_2 from time t_2 till s (1,2) = min (S(2,{1,2}), t_3). If s (1,2) < t_3 then

1

t_3.

Step 3.2 Use p = $\frac{}{i+1-j}$ $k = e_j$ from time s (i, j) till s (i, j – 1): = min (S(j, {1,2,…,i}), t_{i+1}). If j=1 then end.

Step 3.3 If s (i, j – 1) < t_{i+1} then take j = min (j : j ∈ J (t, {1,…,i})) and go to step 3.2

Step 4 From t = t_K to t = τ, use all transmission opportunities to send an RLC of information packets, with coefficients picked uniformly at random in F_q.

In this section, possible rateless codes should be identified and quantify the gains brought by coding. Rateless erasure codes are a class of erasure codes with the property that a potentially limitless sequence of coded packets can be generated from a given set of information packets; information packets, in turn, can be recovered from any subset of the coded packets of size equal to or only slightly larger than K (the amount of additional needed packets for decoding is named “overhead”). As in the previous section, assume that redundant packets are created only after tK, i.e., when all information packets are available. The case when coding is started before receiving all information packets is postponed to the next section. Since coded packets are generated after all information packets have been sent out, the code must be *systematic* because information packets are part of the coded packets.

Amongst rateless codes, LT codes and Raptor codes are near to optimal in the sense that the overhead can be arbitrarily small with some parameters. The coding matrix of each of them has a specific structure in order to reduce encoding and decoding complexity. Only

Raptor codes exist in a systematic version. Network codes are more general rateless codes as generating coded packets relies on random linear combinations (RLCs) of information packets, without any (sparsity) constraint for the matrix of the code. Their overhead can be considered as 0 for high enough field order. That is why in this section the analysis of the optimal control for network codes are provided. But, it is straightforward to extend these results to systematic Raptor codes.

After tK, at each transmission opportunity, the source sends a redundant packet (a RLC of all information packets) with probability *u*. Indeed, from tK, any sent random linear combination carries the same amount of information of each information packet, and hence from that time, the policy is not function of a specific packet anymore, whereby *u* instead of

u. In each sent packet, a header is added to describe what are the coefficients, chosen uniformly at random, of each information packet. The decoding of the K information packets is possible at the destination if and only if the matrix made of the headers of received packets has rank K. Note that, in this case, the coding is performed only by the source since the relay nodes cannot store more than one packet.

.

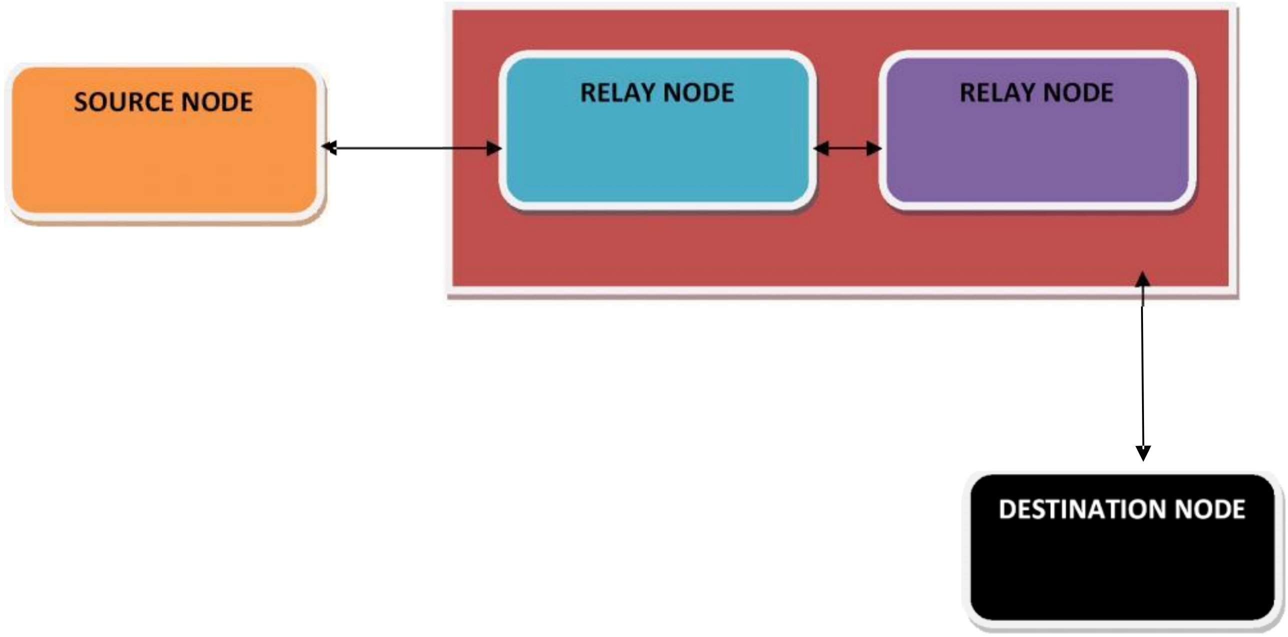

Fig. 5.1: System Architecture

7. CONCLUSION

We have addressed the problem of optimal transmission and scheduling policies in DTN with two-hop routing under memory and energy constraints, when the packets of the file to be transmitted get available at the source progressively. We solved this problem when the source can or cannot overwrite its own packets, and for WC and non WC policies. We extended the theory to the case of fixed rate systematic erasure codes and rateless random linear codes. Our model includes both the case when coding is performed after all the packets are available at the source, and also the important case of random linear codes, that allows for dynamic runtime coding of packets as soon as they become available at the source.

REFERENCES

[1] E. Altman, F. De Pellegrini, and L. Sassatelli, "Dynamic control of coding in delay tolerant networks," in Proc. 2010 IEEE INFOCOM, pp. 1–5.

[2] E. Altman and F. De Pellegrini, "Forward correction and Fountain codes in delay tolerant networks," in Proc. 2009 IEEE INFOCOM, pp. 1–5.

[3] T. Spyropoulos, K. Psounis, and C. Raghavendra, "Efficient routing in intermittently connected mobile networks: the multi-copy case," ACM/IEEE Trans. Netw., vol. 16, no. 1, pp. 77–90, Feb. 2008.

[4] E. Altman, T. Bas¸ar, and F. De Pellegrini, "Optimal monotone forwarding policies in delay tolerant mobile ad-hoc networks,"

in Proc. 2008 ACM/ICST Inter-Perf.

[5] J. Metzner, "An improved broadcast retransmission protocol," IEEE Trans. Commun., vol. 32, no. 6, pp. 679–683, June 1984.

[6] J. Nonnenmacher, E. Biersack, and D. Towsley, "Parity-based loss recovery for reliable multicast transmission," IEEE/ACM Trans. Netw., vol. 6, no. 4, pp. 349–361, 1998.

[7] S. Jain, M. Demmer, R. Patra, and K. Fall, "Using redundancy to cope with failures in a delay tolerant network," SIGCOMM Comput. Commun. Rev., vol. 35, no. 4, pp. 109–120, 2005.

[8] Y. Wang, S. Jain, M. Martonosi, and K. Fall, "Erasure-coding based routing for opportunistic networks," in Proc. 2005 ACM SIGCOMM Workshop Delay-Tolerant Netw., pp. 229–236.

[9] J. Widmer and J.-Y. Le Boudec, "Network coding for efficient communication in extreme networks," in Proc. 2005 ACM SIGCOMM Workshop on Delay-Tolerant Networking, pp. 284–291.

[10] Y. Lin, B. Liang, and B. Li, "Performance modeling of network coding in epidemic routing," in Proc. 2007 ACM MobiSys Workshop Mobile Opportunistic Netw., pp. 67–74.

[11] Y. Lin, B. Li, and B. Liang, "Efficient network-coded data transmissions in disruption tolerant networks," in Proc. 2008 IEEE INFOCOM, pp. 1508–1516.

[12] R. Groenevelt and P. Nain, "Message delay in MANETs," in Proc. 2005 ACM SIGMETRICS, pp. 412–413.

[13] X. Zhang, G. Neglia, J. Kurose, and D. Towsley, "Performance modeling of epidemic routing," Elsevier Comput. Netw., vol. 51, pp. 2867–2891, July 2007.

[14] T. G. Kurtz, "Solutions of ordinary differential equations as limits of pure jump Markov processes," J. Applied Probability, vol. 7, no. 1, pp. 49–58, 1970.

[15] M. Bena¨ım and J.-Y. Le Boudec, "A class of mean field interaction models for computer and communication systems," Performance Evaluation, 2008.

[16] E. Altman, G. Neglia, F. De Pellegrini, and D. Miorandi, "Decentralized stochastic control of delay tolerant networks," in Proc. 2009 IEEE INFOCOM, pp. 1134–1142.

[17] M. Luby, "LT Codes," in *Proc. 43rd IEEE Symp. Foundations of Computer Sciences*, Vancouver BC, Canada, November 2002.

[18] A. Shokrollahi, "Raptor codes," *IEEE Tranactions on Information Theory*, vol. 52, no. 6, pp. 2551–2567, June 2006.

[19] D. S. Lun, M. Medard, and M. Effros, "On coding for reliable communication over packet networks," in *Proc. 42nd Annual Allerton Conference on Communication, Control, and Computing*, September 2004, pp. 20–29.

[20] C.Fragouli, J.Widmer, "Network coding : an instant premer", SIIGCOMM Comput.

Commun. Rev., vol36, no. 1,pp.63-68, 2006

[21] A. Ali, E.Altman, T.Chahed, D.Fiems,

M.Panda , and L.Sassatelli, "Estimating

file- spread in delay tolerant networks

under two-hop routing," in Proc. 2012 IFIP

netw.,pp.

277-290.

[22] K. Price and R. Storn, "Differential Evolution: A Simple and Efficient Heuristic for

Global Optimization Over Continuous Spaces," *J.Global Optimiz.*, vol. 11, pp. 341–

359, 1997.

[23] A.W. Marshall and I. Olkin, Inequalities:

Theory of Majorization and its

Applications, Academic Press, 1979.