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Optimal Transmission and Scheduling in Delay Tolerant Network

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ABSTRACT: Delay-tolerant networking (DTN) is an approach to computer network architecture that seeks to address the technical issues in heterogeneous networks that may lack continuous network connectivity. Generally in networks the ability to transport, or route, data from a source to a destination is a fundamental ability all communication networks must have. Delay and disruption-tolerant networks (DTNs) are characterized by their lack of connectivity, resulting in a lack of instantaneous end-to-end paths. In this challenging environment we are able to effectively forward the packets from source to destination. When we need to transfer a large file from source to destination then here we are making all these packets available at source and then transfer as small packets. We are analyzing the performance of packets arriving at the source and then considering the linear blocks and rate less random linear coding to efficiently generate the redundancy as well as the energy constraint in the optimization. And then these small packets of large file are forward through the multiple paths to destination by using optimal user centric allocation and scheduling the packets at receiver side. 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 numerically assess the higher efficiency of piecewise-threshold policies compared with other policies by developing heuristic optimization of the thresholds for all flavours of coding considered.

KEYWORDS: Delay tolerant networks, mobile ad hoc networks, optimal scheduling, rate-less codes, network coding.

1. INTRODUCTION

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. In these networks, for message delivery, nodes use store-carry-and-forward paradigm to route the messages. The examples of this networks are wildlife tracking, military networks etc. However, effective forwarding based on a limited knowledge of contact behavior of nodes is challenging. it becomes crucial to design efficient resource allocation and data storage protocols. Although the connectivity of nodes is not constantly maintained, it is still desirable to allow communication between nodes. Each time the source meats a relay node, it chooses a frame i for transmission with probability ui. In the basic scenario, the source has initially all the packets .Under this assumption that the transmission policy has a threshold structure: it is optimal to use all opportunities to spread packets till some time σ depending on the energy constraint, and then stop. This policy resembles the well-known "Spray-and-Wait" policy. In this work we assume a more general arrival process of packets: they need to be simultaneously available for transmission initially, i.e., when forwarding starts, as assumed. This is the case when large multimedia files are recorded at the source node that sends them out (in a DTN fashion) after waiting for the whole file reception. This paper focuses on general packet arrivals at the source and two-hop routing. We distinguish two cases: when the source can overwrite its own packets in the relay nodes, and when it cannot. We derive the conditions for optimality in terms of probability of successful delivery and mean delay.

- In the case of non-overwriting, we 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.

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- We extend the above analysis to the case where copies are coded packets, generated both with linear block codes and rate less coding. We also account for an energy constraint in the optimization.
- We 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 flavours of coding considered. As well, in the overwriting case, we show that work-conserving policies are the best without any energy constraint.

II. RELATED WORK

In forward error correction method Several satellites need to receive several data packets, that may need retransmission due to channel errors .Because many sites may need retransmissions, the problem is to avoid the phenomenon of ACK implosion due to several sites requesting repairs .several works to combine FEC and acknowledgment-based retransmission protocols, The effort there was to improve timeliness of packet delivery in multicasting multimedia streams which are subject to hard delay constraints. In DTNs the framework is different since the challenge is to overcome frequent disconnections. In previous they 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.

In 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. In other paper that 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. In ODE-based models are employed under epidemic routing; in that work, semi-analytical numerical results are reported describing the effect of finite buffers and contact times. The same authors investigate the use of network coding using the Spray-and-Wait algorithm and analyze the performance in terms of the bandwidth of contacts, the energy constraint and the buffer size.

III. PROBLEM DEFINITION

Consider a network that contains N + 1 mobile node. Two nodes are able to communicate when they come within reciprocal radio range and communications are bidirectional .We assume that the duration of such contacts is sufficient to exchange all frames: this let us consider nodes meeting times only, i.e., time instants when a pair of not connected nodes fall within reciprocal radio range. Time between contacts of pairs of nodes is exponentially distributed with given inter-meeting intensity. A file contains K frames. The source of the file receives the frames at some times $t_1 \leq t_2 \leq \ldots \leq t_k$. T_i are called the arrival times.

The transmitted file is relevant during some time τ. By that we mean that all frames should arrive at the destination by time $t_1 + \tau$. We 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 $u_i(t)$. Consider two-hop routing In this we used two concept 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 we use rate less code and block code for removing the overwriting case due to the transmission of packet . The symbols that mainly used in this paper are presented in table 1.

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TABLE 1: MAIN NOTATIONS USED THROUGHOUT PAPER

Symbol	*Meaning*
N	number of nodes (excluding the destination)
K	number of packets composing the file
H	number of redundant packets
λ	inter-meeting intensity
τ	timeout value
$X_i(t)$	fraction of nodes (excluding the destination) having packet i at time t
$X(t)$	summation $\sum_i X_i(t)$
$\widehat{X}_i, \widehat{X}$	corresponding sample paths
z	$:=X(0)$ will be taken 0 unless otherwise stated.
$u_i(t)$	forwarding policy for packet i; $\mathbf{u} = (u_1, u_2, \ldots, u_K)$
u	sum of the u_is
$Z_i(t)$,Z_i	$Z_i(t) = \int_0^T X_i(u)du$, $Z_i = Z_i(\tau)$, $\mathbf{Z}(t) = (Z_1(t), Z_2(t), \ldots)$, $\mathbf{Z} = \mathbf{Z}(\tau)$, $Z = \sum Z_i$
$D_i(\tau)$	probability of successful delivery of packet i by time τ
$P_s(\tau)$	probability of successful delivery of the file by time τ; $P_s(\tau, K, H)$ is used to stress the dependence on K and H
$\mathbb{R}_+$	nonnegative real numbers

Rate less code and block code is used for 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. We use erasure coding technique to increase the reliability and to further decrease the cost of routing. For a given desired delivery rate and deadline for delivery, we find the optimum parameters to obtain the smallest cost both in single period and two period erasure coding based routing. We 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. We analyze real DTN traces and detect the correlations between the movements of different nodes using a new metric called conditional intermeeting time. We 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.

IV. PROBLEM STATEMENT

We shall now introduce two classes of forwarding policies.

Definition 3.1: We define u to be a work-conserving (WC) policy if whenever the source meets a node then it forwards it a packet, unless the energy constraint has already been attained.

Definition 3.2: We define u to be a piecewise-threshold policy if the source systematically transmits up to threshold time s_i after receiving packet i, and then stops forwarding until the next packet arrives. We shall study the following optimization problems:

- **P1.** Find **u** that maximizes the probability of successful delivery till time τ (over all kinds of policies).
- **P2.** Find **u** that minimizes the expected delivery time over the WC policies. Policy **u** is called uniformly optimal for problem P1 if it is optimal for problem P1 for all $\tau > 0$.

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ARCHITECTURE

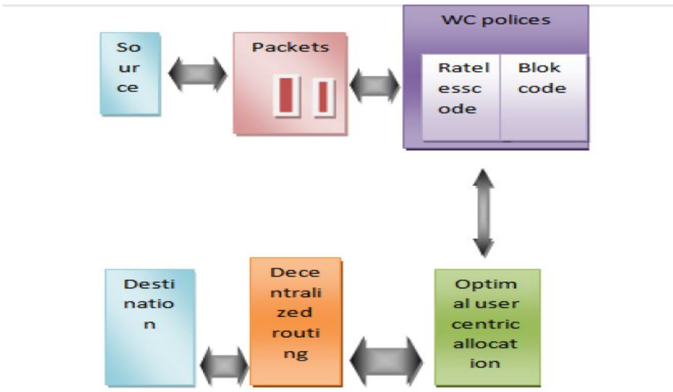

FIG 1: PACKETS ARRIVAL

A. Energy constraints

Denote by E(t) the energy consumed by the whole network for transmitting and receiving a file during the time interval [0, t]. It is proportional to X(t)−X(0) since we assume that the file is transmitted only to mobiles that do not have the file, and thus the number of transmissions of the file during [0, t] plus the number of mobiles that had it at time zero equals to the number of mobiles that have it. Also, let $\varepsilon > 0$ is the energy spent to forward a frame during a contact (notice that it includes also the energy spent to receive the file at the receiver side). We thus have $\varepsilon(t) = \varepsilon(X(t) - X(0))$.

B.Performance measure

Consider time t sampled over the discrete domain, i.e., t ∈. For our case, the drift defined is $f^{(N,i)}(m) = E(\hat{X}_i(N)(t + 1) - \hat{X}i(N)i(t)|\hat{X}(N)(t) = m)$Owing to the model, we have $f^{(N,i)}(m) = u_i(t)\beta(1 - \sum^{K}_{k=1} m_i)$ in the non overwriting case, and $f^{(N,i)}(m) = \beta u_i(t)(1 - m_i) - \beta m_i (u(t) - u_i(t))$ in the overwriting case

C.Rateless codes

In this section, we want to identify the possible rate less codes and quantify the gains brought by coding. Rate less 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").

Information frames are the K frames received at the source at $t_1 \le t_2 \le \cdots \le t_K$. The encoding frames (also called coded frames) are linear combinations of some information frames, and will be created according to the chosen coding scheme. From $t = t_K$ to $t = \tau$, use all transmission opportunities to send a random linear combination of information frames, with coefficients picked uniformly at random. When all information frames are available. The case when coding is started before receiving all information frames is postponed to the next section. In this section we provide the analysis of the optimal control with random linear network coding. Note that, in our case, the coding is performed only by the source since the relay nodes cannot store more than one frame. For each generated encoding frame, the coefficients are chosen uniformly at random for each information frame.

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TABLE II
ALGORITHM A

A1 Use $\mathbf{p}_t = e_1$ at time $t \in [t_1, t_2)$.
A2 Use $\mathbf{p}_t = e_2$ from time t_2 till $s(1,2) = \min(S(2, \{1,2\}), t_3)$. If $s(1,2) < t_3$ then switch to $\mathbf{p}_t = \frac{1}{2}(e_1 + e_2)$ till time t_3.
A3 Define $t_{K+1} = \tau$. Repeat the following for $i = 3, ..., K$:
  A3.1 Set $j = i$. Set $s(i,j) = t_i$
  A3.2 Use $\mathbf{p}_t = \frac{1}{i+1-j} \sum_{k=j}^{i} e_k$ from time $s(i,j)$ till $s(i,j-1) := \min(S(j, \{1,2,...,i\}), t_{i+1})$. If $j = 1$ then end.
  A3.3 If $s(i,j-1) < t_{i+1}$ then take $j = \min(j : j \in J(t, \{1,...,i\}))$ and go to step [A3.2].

• Let $J(t,A)$ be the subset of elements of A that achieve the minimum $I(t,A)$.
• Let $S(i,A) := \sup(t : i \notin J(t,A))$ for i in A.
• Define e_i to be the policy that sends packets of type i with probability 1 at time t and does not send packets of other types.

Algorithm A in Table II 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 A3.2). If the minimum is reached (at some threshold s), then it increases the fraction of all packets currently having minimum CCI, seeking now to equalize towards the second smallest CCI, sharing equally the forwarding probability among all such packets. The process is repeated until the packet arrives: hence, the same procedure is applied over the novel interval.

V. THE CONSTRAINED PROBLEM

Let u be any policy that achieves the constraint E $(\tau) = \mathcal{E}X_e$ as, We make the following observation. The constraint involves only $X(t)$. It thus depends on the individual $Xi(t)$'s only through their sum; the sum $X(t)$, in turn, depends on the policies u_i's only through their sum $u(t) = \sum^{K}_{i=1} u_i(t)$.

WC policies: If a policy is WC and has to meet an energy constraint, then it is such that: $u = 1$ till some time s and is then zero. s is the solution of $X(s) = z + X_e$, either in the overwriting or non-overwriting cases. Algorithm A can be used to generate the optimal policy components $u_i(t)$, $i = 1, . . .,K$: in particular, it will perform the same type of equalization performed in the unconstrained case until the bound is reached and it will stop thereafter.

General policies: The optimal policies satisfying a certain energy constraint is piecewise-threshold, with thresholds s_i possibly strictly lower than t_i+1, for $i = 1. . . K$ and t_i+1= τ for the sake of notation.

VI. RATELESS CODE

In this, we want to identify the possible rate less codes for the settings described, and quantify the gains brought by coding. Rate less 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").

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A.Rateless coding after t_K:

As in the previous section, we assume that redundant packets are created only after t_K, i.e., when all information packets are available. The case when coding is started before receiving all information packets is postponed to the subsection. 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 rate less 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. Random network codes are more general rate less 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 finite field order. That is why in this section we provide the analysis of the optimal control for network codes. But, it is straightforward to extend these results to systematic Raptor codes.

After t_K, at each transmission opportunity, the source sends a redundant packet (an RLC of all information packets) with probability $u(t)$. Indeed, from t_K, any sent RLC 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 $u(t)$ instead of $\mathbf{u}(t)$. 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 our case, the coding is performed only by the source since the relay nodes cannot store more than one packet.

B. Rateless coding before t_K

We now consider the case where after receiving packet *I* and before receiving packet $i + 1$ at the source, we allow to code over the available information packets and to send the resulting coded packets between t_i and t_i+1. LT codes and Raptor codes require that all the information packets are available at the source before generating coded packets. Owing to their fully random structure, network codes do not have this constraint, and allow generating coded packets online, along the reception of packets at the source. We present how to use network codes in such a setting. The objective is the successful delivery of the entire file (the K information packets) by time τ1. Information packets are not sent anymore, only coded packets are sent instead.

TABLE II - ALGORITHM B

C1 Use $\mathbf{p}_t = e_1$ at time $t \in [t_1, t_2)$.

C2 Use $\mathbf{p}_t = e_2$ from time t_2 till $s(1,2) = \min(S(2, \{1,2\}), t_3)$. If $s(1,2) < t_3$ then switch to $\mathbf{p}_t = \frac{1}{2}(e_1 + e_2)$ till time t_3.

C3 Repeat the following for $i = 3, ..., K-1$:

- C3.1 Set $j = i$. Set $s(i,j) = t_i$
- C3.2 Use $\mathbf{p}_t = \frac{1}{i+1-j}\sum_{k=j}^{i} e_k$ from time $s(i,j)$ till $s(i, j-1) := \min(S(j, \{1, 2, ..., i\}), t_{i+1})$. If $j = 1$ then end.
- C3.3 If $s(i, j-1) < t_{i+1}$ then take $j = \min(j : j \in J(t, \{1, ..., i\}))$ and go to step [C3.2].

C4 From $t = t_K$ to $t = \tau$, use all transmission opportunities to send an RLC of information packets, with coefficients picked uniformly at random in $\mathbb{F}_q$.

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VII. ADDING FIXED AMOUNT OF REDUNDANCY WITH OPTIMAL BLOCK-CODES

We now consider adding forward error correction: we add H redundant packets and consider the new file that now contains K + H packets. The channel between the source and the destination up to time τ can be seen as an erasure channel. For such channel, maximum-distance separable erasure codes exist, such as Reed-Solomon codes, for which it is sufficient to receive any K packets out of the K +H to ensure successful decoding of the entire file at the receiver (i.e., retrieval of the K information packets). We assume that all redundant packets are available (created at the source) once all K information packets have been received, that is from tK onwards. The same results would hold if coded packets are created at separate times ti > tK for i = K +1, . . .,K + H. Now we introduce the result that specifies how to optimize WC policies when block codes are adopted.

VIII. FEATURE ENHANCEMENT

Complexity: The decoding complexity of random network codes ($O(K^3)$) may not be a problem in the DTN context as the decoding by progressive/incremental Gauss-Jordan elimination as the packets arrive at a slow rate can limit the computational burden per time unit. If one would like to use systematic Raptor codes for coding after t_k.

Multi-hop routing: Our work holds also for multi-hop routing, because the optimality condition stated in relieson the concavity of the function $\zeta(h) = 1 - \exp(-\lambda h)$. The source cannot keep track of the exact $Z_i(t)$ anymore but it can still get an approximation of the $Z_i(t)$: either by implementing the analytical fluid model, or by an external observer.

Buffer size: The case of multi-packet memory can be derived.

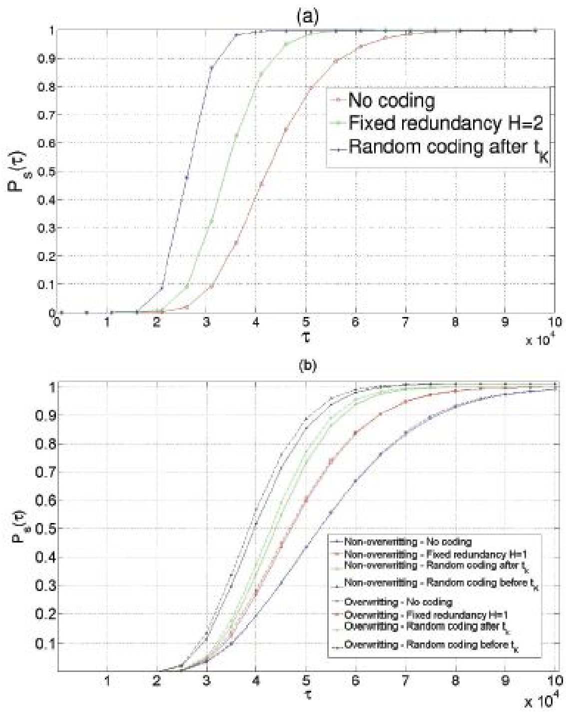

Fig:$Ps(\tau)$ for WC policies based on Algo. A, under various coding schemes. Parameters are N = 100, (a) β = 2.10−5, K = 10, **t** = (119, 1299, 1621, 1656, 3112, 3371, 4693, 5285, 5688, 7942), non overwriting case. (b) β = 8.10−6, K = 4, **t** = (1000, 5000, 7000, 20000).

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IX. CONCLUSION

Information is send to the destination after available of entire data at the source side. We use two concepts overwriting and non-overwriting cases non-overwriting case are highly efficient but overwriting case without constraints are not efficient, so we use rateless code and block code for removing the overwriting case for the transmission of packet. Rateless code and block code is used for share the information sequence to the receiver without data loss, overwritting and delay. For data transmission the multi path is created 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 for 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. This process can use to efficiently send the data from source side to the destination side using delay tolerant network.

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