# Manets: Increasing N-Messages Delivery Probability Using Two-Hop Relay with Erasure Coding

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**ABSTRACT:**
*The lack of a thorough understanding of the fundamental performance limits in mobile ad hoc networks (MANETs) remains a challenging barrier stunting the commercialization and application of such networks. The proposed system is using a method such as two-hop relay algorithm with erasure coding to increase the message delivery probability of a MANETs. The two-hop relay algorithm with erasure coding used for the message that is erasure coded into multiple frames (coded blocks) at each source node. And also, a finite-state absorbing Markov chain framework is developed to characterize the complicated message delivery process in the challenging MANETs. Based on the developed framework, closed-form expressions are further derived for the message delivery probability under any given message lifetime and message size by adopting the blocking matrix technique where the important issues of interference, medium contention and traffic contention are carefully integrated. To further improve our proposed systems a delivery of n-distinct message is simultaneously send from source to destination.*

**Keywords:** *Mobile ad hoc networks, delivery probability, two-hop relay, erasure coding.*

## I. INTRODUCTION:

A mobile ad hoc network (MANET) is a peer-to-peer network without any pre-existing infrastructure or cen-tralized administration, which consists of fully self-organized mobile nodes. As it can be rapidly deployed and flexibly reconfigured, the MANET has found many promising appli-cations, such as the disaster relief, emergency response, daily information exchange, etc., and thus becomes an indispensable component among the next generation networks [1], [2].

Since their seminal work in [3], a significant amount of work has been done for a thorough understanding of the delivery delay performance of various routing protocols in MANETs. Zhang et al. in [4] developed an ODE (ordinary differential equations) based framework to analyze the delivery delay of epidemic routing and its variants. Later, Hanbali et al. focused on a multicopy two-hop relay algorithm and explored the impact of packet lifetime (time-to-live TTL) on the packet delivery delay in [5], [6]. Recently, Liu et al. derived closed-form expressions for the packet delivery delay of erasure coding enhanced two-hop relay in [7] and that of group-based two-hop relay in [8].

The delivery delay study [3]–[8], although important and meaningful, can only tell the expected time it takes a routing protocol to deliver a message (or packet) from the source to the destination, i.e., the mean time required to achieve the delivery probability 1, which is actually a simple extreme case of the delivery probability study. Obviously, it is of more interest for network designers to know the corresponding delivery probability under any given message lifetime (or permitted delivery delay). Further notice that in the challenging MANET environment, multiple message replicas are often propagated to improve the delivery performance, where a relay node receiving a message may forward it or carry it for long periods of time, even after its arrival at the destination. Such combination of message replication and long-term storage imposes a severe overhead on the mobile nodes which are usually not only power energy-constrained but also buffer storage-limited. Thus, the message lifetime should be carefully tuned so as to reduce the network resource consumption in terms of buffer occupation and power consumption while simultaneously satisfy the specified delivery performance requirement.

It is noticed that there have been some efforts in literature focusing on the delivery probability study. Panagakis et al. in [9] analytically derived the message delivery probability of two-hop relay under a given time limit by approximating the cumulative distributed function (CDF) of message delivery delay, with the assumption that for any node pair the message can be successfully transmitted whenever they meet each other. In [10], Whitbeck et al. explored the impact of message size, message lifetime and link lifetime on the message delivery ratio (probability) of epidemic routing by treating the intermittently connected mobile networks (ICMNs) as edge-Markovian graphs, where each link (edge) is considered independent and has the same transition probabilities between “up" and “down" status. Later, Krifa et al. in [11] explored the impact of message scheduling and drop policies on the delivery probability performance of epidemic routing, and proposed a distributed scheduling and drop policy based on statistical learning to approximate the optimal performance. More recently, the optimization issue of message delivery probability under specific energy constraints and message lifetime requirement has also been intensively addressed in the context of delay tolerant networks (DTNs) in which the basic two-hop relay was adopted for packet routing and a wireless link becomes available whenever two nodes meet each other.

A common limitation of the available models is that, all these works assumed a single flow (source-destination pair) in their analysis such that all other nodes act as pure relays for this flow. Such models, although simple and easy to use, may neglect an important fact that for the general MANET scenarios, multiple traffic flows may co-exist and a relay node may simultaneously carry messages belonging to multiple flows. Moreover, all these models (no matter for the ICMNs or for the DTNs) focus on a very special MANET scenario, i.e., the sparsely distributed MANET, by assuming that whenever two nodes meet together they can transmit with each other. Obviously, the available models cannot be applied for delivery probability analysis in the gen-eral MANETs where the interference and medium contention issues are of significant importance. In this paper, we study the delivery probability performance of two-hop relay MANETs with a careful consideration of the above important issues. The main contributions of this paper are summarized as follows.

We focus on the two-hop relay algorithm in MANETs with erasure coding and more general traffic pattern, where the message at each source node is erasure coded into multiple frames (coded blocks). We develop a general finite-state absorbing Markov chain theoretical framework to model the complicated message spreading process in the challenging MANETs, which can also be used to analyze the delivery probability performances under other popular routing protocols, like the epidemic Routing. Based on the Markov chain framework, we further derive closed-form expressions for the corresponding message delivery probability under any given message lifetime and message size by adopting the blocking matrix technique, where the important issues of interference, medium contention and traffic contention in MANETs are carefully incorporated into the analysis.

Extensive simulation studies are conducted to validate our theoretical framework, which indicates that the new framework can be used to accurately predict the message delivery probability in MANETs with two-hop relay and erasure coding, and characterizes how the delivery probability varies with the parameters of message size, replication factor and node density there. The rest of this paper is outlined as follows. Section II introduces the system models, the routing protocol and the scheduling scheme considered in the paper. In Section III, we develop a Markov chain theoretical model for the delivery probability analysis under any given message lifetime and message size.

## II. PRELIMINARIES

### 2.1. System Models

The considered mobile ad hoc network is a unit torus with n mobile nodes. The torus is evenly divided into m × m equal cells (or squares), each cell of side length 1/m as shown in Fig. 1(a). Time is slotted and nodes randomly roam from cell to cell according to the i.i.d. mobility model , which is defined as follows: at time slot t = 0, a node is initially placed in one of the m2 cells according to the uniform distribution. The node randomly selects a cell from the m2 cells with equal probability of 1/m2 independent of other nodes, and moves tothe selected cell at time slot t = 1. The node then repeats this process in every subsequent time slot. One can see that at each time slot, the n nodes are uniformly and randomly distributed in the m2 cells. Since the node movements are also independent from time slot to time slot, the nodes are totally reshuffled at each time slot.

We employ the protocol model in [25] to address the interference among simultaneous link transmissions. Similar to [23], we assume that each time slot will be allocated only for data transmissions in one hop range. The data transmission model is defined as follows: suppose node Ti is transmitting to node Ri at time slot t as shown in Fig. 1(a), and denote by Tit and Rit the positions of Ti and Ri, respectively. According to the protocol model, the data transmission from Ti to Ri can be successful if and only if the following two conditions hold for any other simultaneous transmitting node Tj :

$$|Tit - Rit| \leq r \quad (1)$$

$$|Tjt - Rit| \geq (1 + \Delta)|Tit - Rit| \quad (2)$$

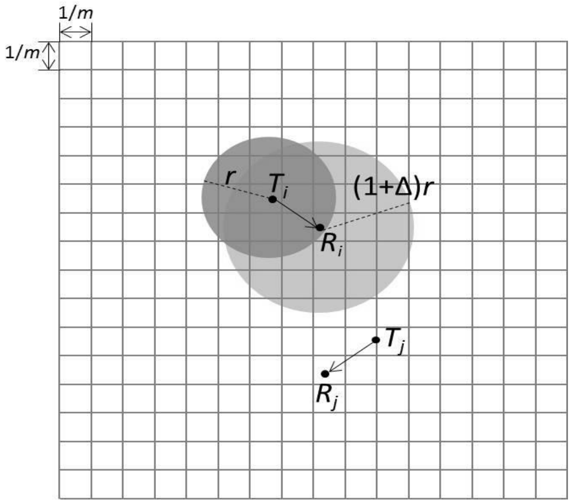
Here r is the transmission range adopted by each node, and $\Delta > 0$ is a protocol specified factor to represent the guardzone around each receiver.

In order to fully characterize the traffic contention issue in MANETs, we consider here the permutation traffic pattern , where each node has a locally generated traffic flow to deliver to its destination and also needs to receive a traffic flow originated from another node. Since there are n mobile nodes in the network, it is easy to see that there exist in total n distinct traffic flows. we assume that the local traffic flow at each node has only a single message. Without loss of generality, we focus on a tagged flow hereafter and denote its source and destination by S and D, respectively.

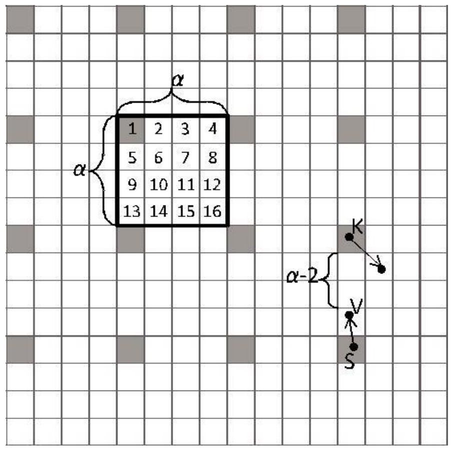
For the tagged flow, the message generated at the source S is assumed to have in total ω blocks ($\omega \geq 1$), where a single block can be successfully transmitted during a time slot (or meeting duration). We further assume that the message is relevant during τ time slots, i.e., the message is labeled with a lifetime of τ time slots, and will be dropped from the network if it fails to make itself to the destination D within τ time slots.

Remark 1: Note that the node mobility is homogeneous under the i.i.d. model, where during each time slot all node pairs have the same probability to encounter and the n nodes are uniformly and randomly distributed in the m2 cells. Such features of homogeneous node meeting and uniform node dis-tribution, although simple and easy to use, are different from other more practical node distributions, like the correlated distribution, the clustered distribution, the home-point distri-bution, etc., where nodes exhibit significant inhomogeneities in spatial distribution over the network area.

Remark 2: The main difficulties in extending the i.i.d. model to take into account more complex mobility, such as the random walk model, random waypoint model, random direction model, correlated mobility model, reference point group mobility, etc., are two folds: the first difficulty is to characterize the node meeting process which depends solely on the node mobility, and the second one is to derive the data transmission probability during each node meeting which is related to both the spatial distribution and data transmissions of other nodes.




(a) Illustration of the transmission model.




(b) Cells in a transmission-group with α = 4.

Figure. 1. Illustration of a cell-partitioned network with m = 16.

It is notable that in MANETs, even though a node pair meet together in a time slot they may fail to transmit data due to the interference caused by other simultaneous data transmissions in the network. These two difficulties combined together make the analytical modeling of delivery performance in MANETs much more challenging. Actually, the main reason behind adopting the simple i.i.d. model is that it is very helpful to keep the theoretical analysis tractable and thus enables closed-form analytical results to be developed for the message delivery probability in the challenging MANETs.

**2.2. Two-Hop Relay with Erasure Coding**

The two-hop relay, since first proposed by Grossglauser and Tse (2001) in [11], has been extensively explored in literature and proved to be a popular and efficient routing protocol for DTNs. However, its delivery performance remains largely unknown in the general MANET environment, where the interference may create extra delay in the delivery of packets. It is further noticed that extensive simulation delay performance of two-hop relay in DTNs can be improved via incorporating the erasure coding technique. Therefore, we focus on the two-hop relay with erasure coding in this paper and develop a theoretical framework to analytically study its delivery performance.

According to the two-hop relay algorithm with erasure coding [7], [10], for the tagged flow, the message is first erasure coded into $\omega \cdot \beta$ equal sized frames (or code blocks) after it is locally generated at S, where $\beta$ is the replication factor. Since each frame is almost the same size as the original block, we assume that it can also be successfully transmitted during a time slot. Any $(1 + \varepsilon) \cdot \omega$ frames can be used to successfully reconstruct the message, where _ is a small constant and it varies with the adopted erasure coding algorithm. Similar to [7], we ignore the constant $\varepsilon$ here and thus the message can be successfully recovered at the destination D with no less than $\omega$ frames collected before it expires (i.e., within $\tau$ time slots).

After erasure coding the message into $\omega \cdot \beta$ frames, the source node S starts to deliver out these frames according to the two-hop relay algorithm [8]. Every time S is selected as the transmitter via the transmission scheduling scheme, it operates as follows:

Step 1: S first checks whether D is in the transmission range. If so, S conducts with D the "source-to-destination" transmission, where a frame is sent directly to D.

Step 2: For the case that D is not in the transmission range of S, if there is no other node in the one-hop neighborhood of S, S remains idle for the time slot;otherwise, S randomly selects a node, say R, from the one-hop neighborhood as the receiver, and flips an unbiased coin;

If it is the head, S chooses to perform the "source-to-relay" transmission with R. S initiates a handshake with R to check whether R is carrying a frame received from S. If so, S remains idle for the time slot; otherwise, S sends to R a frame destined for D.

Otherwise, S chooses to perform with R the "relay-to-destination" transmission. S first checks whether it is carrying a frame destined for R. If so, S forwards the frame to R; otherwise, S stays idle for the time slot.

It is noticed that distinguished from available works which assumed a simple scenario of single traffic flow, we consider in this paper the permutation traffic pattern to fully characterize the traffic contention issue in MANETs. Under such traffic pattern , node may not only carry the frames of its own message ,but also simultaneously carry multiple frames originated from other nodes in the network. To simplify the analysis and thus keep the theoretical framework tractable, we assume that each frame will be delivered to at most one relay node and each relay node will carry at most one frame from in S.

We consider a single-copy version of the two-hop relay with erasure coding, where S either delivers a frame to D or sends it to a relay node. After sending a frame to a relay node, S retains a copy of the frame as backup; while the relay node will delete the frame from the buffer after forwarding it to D. Therefore, before arriving at D, each frame may have at most two copies in the network, one in the relay node and the other one in S.

### 2.3. Transmission Scheduling

Similar to previous studies we consider a local transmission scenario [7], [8], [9], where a transmitter in a cell can only transmit to receivers in the same cell or other eight adjacent cells (two cells are called adjacent cells if they share a common point). Thus, the transmission range can be accordingly determined as $r = \sqrt{8}/m$. It is easy to see that two links can transmit simultaneously if and only if they are sufficiently far away from each other. To avoid collisions among simultaneous transmitting links and support as many simultaneous link transmissions as possible, we adopt here the transmission-group based scheduling scheme [7], [8], [9].

With such a transmission-group definition, all m2 cells are actually divided into α2 distinct transmission-groups. If each transmission-group becomes active (i.e., has link transmis-sions) alternatively, then each cell will also become active every α2 time slots. As illustrated in Fig. 1(b) for the case $\alpha = 4$, there are in total 16 transmission-groups, and all shaded cells belong to the same transmission-group.

Setting of Parameter α: As shown in Fig. 1(b), suppose node S in an active cell is transmitting to node V in a time slot. It is easy to see that another transmitter, say K, in another active cell is at least $\alpha-2$ cells away from V . According to the protocol interference model , we should have $(\alpha-2)\cdot 1/m \geq (1+\Delta)\cdot r$ to ensure the successful data reception at V . Notice that $\alpha \leq m$ and $r = \sqrt{8}/m$, then the parameter α can be determined as

$$\alpha = \min\{[(1 + \Delta) \sqrt{8} + 2]\ m\} \qquad (3)$$

It is noticed that with the setting of $\alpha = m$, all network cells are divided into m2 distinct transmission-groups, with each transmission-group containing a single cell. Therefore, the network can support only one active transmitter-receiver pair during each time slot. For the transmission-group based scheduling scheme, a node is assumed to be able to obtain the cell id where it resides at the beginning of each time slot. Actually, for a given network cell partition, such hypotheses can be satisfied by adopting the global positioning system (GPS) or some node localization schemes . Therefore, after obtaining the cell id, a node can easily judge whether it is inside an active cell or not for the current time slot, and then the nodes in an active cell can compete to become the transmitter via a distributed coordination function (DCF)-style mechanism.

Remark 3: The transmission-group based scheduling scheme has the following two advantageous features: firstly, it is fully distributed and thus it can be implemented without any centralized management; secondly, it enables closed-form expressions to be derived for the transmission probability under the two-hop relay during each time slot. It is also noticed that in (1) we derive$\sqrt{\alpha}$ according to the possible maximum distance (i.e., $r = \sqrt{8}/m$) between a transmitter-receiver pair in two adjacent cells. However, one can see that the distance between a transmitter-receiver pair selected for each active cell may be less than $\sqrt{8}/m$ with high probability during each time slot. Consequently, the scheduling scheme may unavoidably result in an inefficient spatial reuse due to the fixed setting of α.

## III. MESSAGE DELIVERY PROBABILITY

**I**n this section ,we first introduce some basic probabilities under the two hop relay with erasure coding , develop the Markov chain theoretical framework ,and then proceed to derive the message delivery probability.

### 3.1. Markov Chain Framework

For the tagged flow, as the message generated at the source node S is erasure coded into $\omega \cdot \beta$ frames and is relevant only in τ time slots, the destination node D needs to collect at least ω frames within τ time slots so as to successfully recover the message. If we denote by (j, k) a general transient state during the message delivery process that S is delivering the jth frame and D has already received k distinct frames, and further denote by (∗ , k) a transient state that S has already finished dispatching all $\omega \cdot \beta$ frames while D has only received k of them, $1 \leq j \leq \omega \cdot \beta$, $0 \leq k < \omega$, then we can characterize the message delivery process with a finite-state absorbing Markov chain. Specifically, if the tagged flow is in state (j, k) at the current time slot, only one of the following four transition cases illustrated in Fig. 2 may happen in the next time slot.

SR Case : "source-to-relay" transmission only, i.e., S successfully delivers the jth frame to a new relay node while none of the relays delivers a frame to D. As shown in Fig. 2(a) that under such a transition case, the state (j, k) may transit to two different neighboring states depending on the current frame index j.

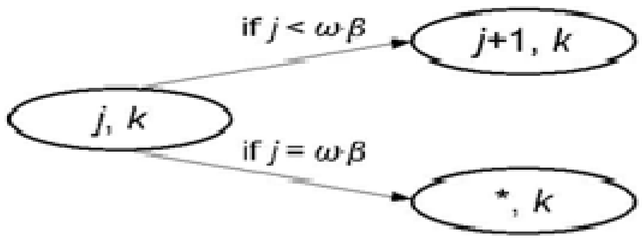



Figure 3.1 SR Case

RD Case : "relay-to-destination" transmission only, i.e., some relay node successfully delivers a frame to D while S fails to deliver out the jth frame to a new relay node. As shown in Fig. 2(b) that there is only one target state (j, k + 1) under the RD case.


Figure 3.1 RD Case

SR+RD Case: both "source-to-relay" and "relay-to-destination" transmissions, i.e., these two transmissions happen simultaneously. We can see from Fig. 2(c) that depending on the value of j there are two possible target states under the SR+RD case.

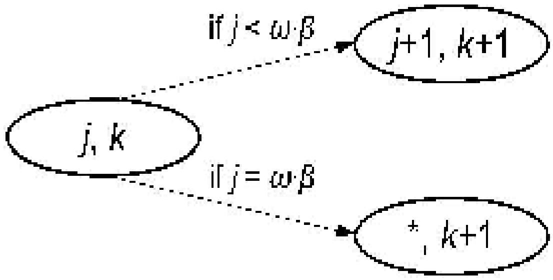



Figure 3.1SR+RD case

SD Case : "source-to-destination" transmission only, i.e., S successfully delivers a frame to D. As shown in Fig. 2(d) that under the SD case, the state (j, k) may transit to (j +1, k +1) or (∗ , k +1), similar to that under the SR+RD case.

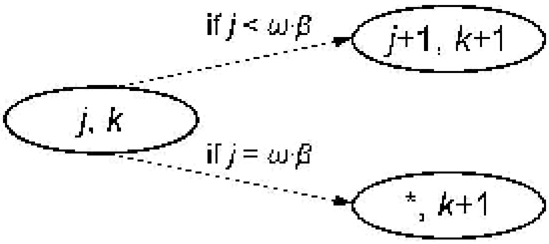



Figure 3.1 SD case

**3.2. Derivations of delivery probability $\varphi$ (□, □, □)**

Before deriving the message delivery probability ,we first node S which is further erasure coded into ω.β frames ,the delivery delay of the message and the timeslot when the destination node D receives ω distinct frames of the message.

For the tagged flow, if we denote by Td the message delivery delay and denote by ϕ(ω,β,τ) the message delivery probability under the message lifetime constraint τ, then we have

$$\phi(\omega, \beta,\tau) = Pr(Td \leq \tau) = \sum_{t=1}^{\tau} Pr(Td = t). \quad (4)$$

Based on the Markov chain framework, now we are ready to derive $\varphi$ (ω,β,τ) .All δ transient states in the Markov chain are arranged into ω rows. We number these transient states sequentially 1,2,…,δ in a left to right and top to bottom way. For these transient states , if we let qij denote the transition probability from state i to state j, then we can define a matrix Q = (qij )δ×δ of transition probabilities among δ transient states there. Similarly, if we let bi denote the one step transition probability from state i to the absorbing state A, then we can also define a vector B = (bi)δ×1 representing the transition probabilities from δ transient states to state A. Notice that Pr(Td = t) in denotes the probability that the ωth frame arrives at the destination D by the end of the tth time slot, i.e., the probability that the Markov chain gets absorbed by the end of the tth time slot. Given that the Markov chain starts from the first state, i.e., state (1, 0), according to the Markov chain theory , then we have

$$Pr(Td = t) = \sum_{i=1}^{\delta} q1j^{(t-1)} . bi \quad (5)$$

Then combining with the fact of previous equation is actually the ij –entry of the matrix $Q^t$ can be further transformed as

$$Pr(Td = t) = e \cdot Qt-1 \cdot B \quad (6)$$

where e = (1, 0, . . . , 0).
Substituting (14) into (12), then we have

$$\begin{aligned}\phi(\omega, \beta, \tau) &= e \cdot Qt-1 \cdot B \\ &= e \cdot (I - Q)-1 \cdot (I - Q\tau) \cdot B \\ &= e \cdot N \cdot (I - Q\tau) \cdot B \quad (7)\end{aligned}$$

where I is the identity matrix, and N = (I − Q)−1 is the fundamental matrix of the Markov chain.

## IV. RESULTS AND DISCUSSION

In this paper, we have investigated the message delivery probability in two-hop relay MANETs with erasure coding. A general Markov chain theoretical framework was developed to characterize the message delivery process, which can also be used to analyze the delivery probability performances under other popular routing protocols. Based on the new theoretical framework, closed-form expressions were further derived for the delivery probability under any given message lifetime and message size. As verified by extensive simulation studies, our framework can be used to efficiently model the message delivery process and thus accurately characterize the delivery probability performance there. Our results indicate that for a two-hop relay MANET with erasure coding, there exists a limiting performance for the delivery probability, which is determined only by the control parameters of message size ω and message lifetime τ . Another interesting finding of ourwork is that the considered MANETs actually exhibit very similar behaviors in terms of delivery probability under different node mobility models, like the i.i.d., random walk and random waypoint.

## V. CONCLUSION

This project can be design a future network in terms of determining a suitable message lifetime, so as to minimize the per node buffer occupation and power consumption while simultaneously meet the specified delivery performance requirement.Note that the theoretical framework and closed-form results developed in this paper only hold for the simple scenario that each node has only a single message to deliver to its destination, and it chooses to conduct a “source-to-relay" or “relay-to-destination" transmission in a probabilistic fashion. Therefore, one future work is to further explore the delivery probability of two-hop relay with erasure coding in a more general scenario, where each node may need to simultaneously deliver k distinct messages, and it conducts the “source-to-relay" or “relay-to-destination" transmission in the best-effort fashion so as to take the full advantage of each transmission opportunity. Another interesting future direction is to extend the theoretical models in this paper to analytically derive the optimum setting of n (i.e., $n*$ ) to achieve the maximum message delivery probability for a given relay scheme setting of ($\omega$, $\beta$, $\tau$ ), or to formally determine the asymptotic (limiting) delivery probability for any specified control parameters of $\omega$ and $\tau$ .This project implemented a Mobile Ad-hoc Network model for the compute message delivery probability. The network is functioned based on effective transmission group scheduling scheme, two-hop relay mechanism and Tornado encoding scheme. The proposed network model sends the multiple selected messages in effective way. Also, a dynamic memory management mechanism is utilized to manage the sending messages. Finally, a modified Markov chain model is utilized to compute the message delivery probability of whole selected message. In future , This project can be design a future network in terms of determining a suitable message lifetime, so as to minimize the per node buffer occupation and power consumption while simultaneously meet the specified delivery performance requirement.

## REFERENCES


[1] “Beyond Shannon: The Quest for Fundamental Performance Limits of Wireless Ad Hoc Networks”, Andrea Goldsmith, Stanford University, Michelle Effros, Caltech Ralf Koetter, Technical University of Munich Muriel Médard, Asu Ozdaglar, and Lizhong Zheng, MIT may 2011.

[2] “Optimal Delay-Throughput Trade-Offs in Mobile Ad Hoc Networks”, Lei Ying, Sichao Yang, and R. Srikant Coordinated Science Lab and Department of Electrical and Computer Engineering University of Illinois at Urbana-Champaign, 2007.

[3] “Optimal Control in Two-Hop Relay Routing”, Eitan Altman, Tamer Basar, and Francesco De Pellegrini, 2004.

[4] “Rethinking Information Theory for Mobile Ad Hoc Networks”, Jeff Andrews, Nihar Jindal, Martin Haenggi, Randy Berry, Syed Jafar, Dongning Guo, Sanjay Shakkottai, Robert Heath, Michael Neely, Steven Weber, Aylin Yener, 2007.

[5] “Routing in Delay/Disruption Tolerant Networks: A Taxonomy, Survey and Challenges”, Yue Cao and Zhili Sun, *Member, IEEE, 2012*

[6] “Annotating Structured Data of the Deep Web”, Hai He1, Weiyi Meng1, Hongkun Zhao1, and Clement Yu Department of Computer Science SUNY at Binghamton, NY 13902, USA

[7] A. A. Hanbali, A. A. Kherani, and P. Nain, “Simple models for the performance evaluation of a class of two-hop relay protocols,” in *Proc. 2007 IFIP Netw. Conf.*

[8] J. Liu, X. Jiang, H. Nishiyama, and N. Kato, “Delay and capacity in ad hoc mobile networks with *f* -cast relay algorithms,” *IEEE Trans. Wireless Commun.*, vol. 10, no. 8, pp. 2738–2751, Aug. 2011.

[9] S. R. Kulkarni and P. Viswanath, “A deterministic approach to through-put scaling in wireless networks,” *IEEE Trans. Inf. Theory*, vol. 50, no. 6, pp. 1041–1049, June 2004.

[10] Y. Wang, S. Jain, M. Martonosi, and K. Fall, “Erasure-coding based routing for opportunistic networks,” in *Proc. 2005 WDTN Conf.*

[11] M. Grossglauser and D. N. Tse, “Mobility increases the capacity of ad hoc wireless networks,” in *Proc. 2001 IEEE INFOCOM.*