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A Review on Dissemination Of Energy-Efficient Broadcast To Channel Randomness In Mobile Networks

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Abstract: **Efficient broadcast in mobile networks is a challenging task due to high dynamic topology and energy efficiency and channel randomness. Based on an in-depth analysis of the popular Susceptible Infectious Recovered (SIR) epidemic broadcast scheme. In this paper a a study on novel energy-efficient broadcast scheme was done through dissemination process. This is able to adapt to fast changing network topology and channel randomness. Dissemination in mobile ad-hoc networks (MANETs) has to propagate a way of sore carry forward. Analytical results are provided to characterize the proposed scheme, including the fraction of nodes that can receive the information and the delay of the information dissemination process.**

Index Terms**—Mobile ad-hoc networks, shadowing, fading, connectivity, epidemic broadcast.**

I. INTRODUCTION

Wireless communications is a type of data communication that is performed and delivered wirelessly. This is a broad term that incorporates all procedures and forms of connecting and communicating between two or more devices using a wireless signal through wireless communication technologies and devices. Wireless communication generally works through electromagnetic signals that are broadcast by an enabled device within the air, physical environment or atmosphere.

A mobile ad-hoc network (MANET) is a self-organizing network comprising mobile devices like smart phones, tablet PCs or intelligent vehicles. In a MANET, information dissemination often relies on local ad-hoc connections that emerge opportunistically as mobile devices move and meet each other. The main challenge of data communication in a MANET is the time-varying nature of ad-hoc connections, which is attributable to two major factors: dynamic network topology and channel randomness.

The dynamic topology of a MANET is caused by the mobility of wireless communication devices. Specifically, as mobile users or intelligent vehicles move over time, the distances between mobile devices are changing constantly, resulting in time-varying wireless links. This makes many commonly-used routing protocols (e.g. the well-known Ad hoc On Demand Distance Vector (AODV) [1] or a basic flooding broadcast algorithm [2]) less effective for MANETs, because they can only disseminate information to the node(s) that is connected to the source by at least one (multi-hop) path at the time instant when the source node transmits. Further, differently from the store-forward pattern that AODV relies on to disseminate information, information dissemination in MANETs has to propagate by way of store-*carry*-forward that allows a node to carry the information over a physical distance and forward to other nodes over time. It has been widely recognized that the dynamic topology of a MANET often resembles the topology of a human network [3], [4], in the sense that the movement of mobile devices in a MANET is not only similar to, but often governed by, the movement of their human owners. In view of this, epidemic schemes (e.g. [3]) have been proposed as a fast and reliable approach to broadcast information in MANETs. On the other hand, unlike the spreading of epidemic disease in human networks, information dissemination schemes in MANETs can often be carefully designed to meet certain goals in addition to information delivery, such as achieving energy efficiency or fulfilling certain delay constraint, as shown in this paper.

Between two devices can also be affected by the availability of spectrum resource. Due to scarcity of the radio frequency spectrum, a frequency band is usually shared by more than one service. Consequently, wireless communication between two mobile devices is affected by temporal availability of spectrum band in the vicinity of the devices. Due to these factors, i.e., the uncertainty in the availability of spectrum band as well as the shadowing and fading effects, wireless connections between nodes are random and time-varying, which must be considered in the design of information dissemination schemes for MANETs. Therefore, it is challenging to establish a distributed broadcast scheme for MANETs that is adaptive to both dynamic topology and channel randomness, while meeting the performance objectives, i.e. delay constraint and energy efficiency.

The rest of this paper is organized as follows: Section II reviews related work. Section III introduces the system model. The analysis of the information dissemination process is pre- sented in Section IV. Section V validates the analysis using simulations. Finally Section VI concludes this paper and dis- cuss's possible future work.

II. RELATED WORK

A number of existing studies on information dissemination in wireless networks (e.g. [6]) focused on connected networks, where a network is said to be *connected* at a time instant if and only if (iff) there is at least one multi-hop path connecting any pair of nodes. In mobile networks, it is often unnecessary or impractical to require that a network is *always* connected [3], due to fast-changing network topology or channel ran- domness. Hence this paper studies information dissemination in MANETs from a percolation perspective, as described formally in Section IV.

Epidemic broadcast schemes are popularly used for infor- mation dissemination in MANETs. In [7], Chen *et al.* studied the information dissemination process using a Susceptible- Infectious (SI) epidemic scheme, where every node carries the received information and forwards it to all nodes coming into the radio range. The SI epidemic scheme is a reliable but costly scheme due to a lack of a proper mechanism to stop the transmission. Considering a Susceptible-Infectious-Recovered (SIR) epidemic scheme, our previous work [4] studied the information dissemination process in a MANET. The SIR epi- demic scheme postulates that nodes need to keep transmitting for a prescribed time period before recovery (i.e. stopping the transmission); nevertheless a long continuous transmitting period required by the scheme can be difficult or costly to implement in reality. Then in a conference version of this work [18], we took shadowing effect into account and proposed the opportunistic broadcast scheme. This paper takes a further step by taking fast fading effect into consideration and investigating the optimal design for the opportunistic broadcast scheme that minimizes the resource consumption.

In [16], Clementi et al. studied the speed of information prop- agation in a mobile network where nodes move independently at random over a square area. They obtained an upper bound on the flooding time, which is the maximum time required for all nodes of the network to be informed. In [17], Jacquet *et al.* studied the information propagation speed in mobile networks where nodes are uniformly distributed in a bounded area. The nodes were assumed to move following an i.i.d. random tra- jectory. An upper bound on the information propagation speed, viz. ratio of the distance traveled by information over a given amount of time was obtained.

Different from the aforementioned two studies on the infor- mation propagation speed (i.e. [16],[17]), this paper focuses on analyzing the fraction of nodes that can receive the information. We choose to focus on the fraction of recipient's nodes because it is a key performance metric for information broadcast in a network using the SIR scheme. Compared with the Susceptible- Infectious (SI) forwarding scheme used in [16],[17],using the SIR scheme a relay node does *not* forward the received packets indefinitely, which reflects the real world scenarios where mo- bile devices usually have limited energy supply and/or buffer size. On the other hand, unlike the SI-like schemes, the SIR scheme does not guarantee that the information can be received by *all nodes* in a network, and consequently the fraction of recipients becomes a key performance metric, which is studied in this paper.

There are other broadcast schemes for MANETs beside epidemic schemes. In [9], Friedman *et al.* reviewed some gossip- based algorithms that can be suitable candidates for information dissemination in MANETs. They pointed out that the design of energy and bandwidth efficient information dissemination schemes for MANETs is a challenging and open problem. They identified that the low nodal density and the lack of global information are two major challenges in effective data forwarding in delay tolerant networks. We further note that in [20], Xiang and Ge et al. first proposed an energy efficiency model for wireless cellular networks, and on that basis built an analytical relationship among the wireless traffic, wireless channel model and the energy efficiency. Their work suggested that the energy efficiency optimization of wireless networks should consider the wireless channel randomness. In this paper, these challenges are tackled by introducing a dis- tributed energy-efficient broadcast scheme taking into account channel randomness.

Recently, vehicular ad-hoc networks have been identified as another valuable application of mobile ad- hoc networks [18]. Due to the rapid development of autonomous driving cars, vehicle-to-vehicle communication network or connected vehicle technology has been attracting increasing interest. Due to the relatively slower speed of infrastructure deployment, in a rather long transitional period, communications in many of these vehicular networks may receive limited infrastructure support. Further, the controversial but increasingly popular car- sharing services create another future application for mo- bile ad-hoc networks. For example, the ad-hoc communication network formed by vehicles and mobile users can significantly reduce the requirement and dependence on mobile network operators. In light of these interesting developments, the simu- lation section uses vehicle ad-hoc network as a typical example to evaluate the analytical results presented in this paper.

III. SYSTEM MODEL

A. Network Model

Suppose that at some initial time instant ($t = 0$), a set of N nodes are independently, randomly and uniformly placed on a torus $(0, L]^2$. It follows that the nodal density is $\lambda = N/L^2$. Then the nodes start to move according to the random direction model (RDM). Specifically, at time $t =$ 0, each node chooses its direction independently and uniformly in $[0, 2\pi)$, and then moves in this direction thereafter at a constant speed V.It has been shown in that under the aforementioned model, at any time instant $t \geq$ 0, the spatial distribution of nodes is stationary and still follows the uniform distribution. Note that the uniform spatial distribution and random direction mobility are both simplified but widely-used models in this field to facilitate the analysis.

A commonly-used radio propagation model in this field is the *unit disk model* (UDM), under which two nodes are directly connected iff the Euclidean distance between them is not larger than the radio range r_0 . More specifically, under the UDM, the received signal strength (RSS) at a receiver separated by distance x from the transmitter is $P_u(x= C p_t x^{-\eta}$, where C is a constant, p_t is the transmission power common to all nodes and η is the path loss exponent. A transmission is successful iff the RSS exceeds a given threshold $p_{\min}$. Therefore, the required transmission power p_t allowing a radio range r_0 is $p_t=(p_{min}/c)$

To incorporate both shadowing and fading effects, we adopt a wireless connection model, named the general connection model. Specifically, let $P_g(p_t x^{-\eta}, Z,$ $\Omega)$: $\Re^+ \times \Re \times \Re \rightarrow [0, 1]$ be the RSS at a receiver separated by distance x from the transmitter, where Z and Ω (called *channel factors*) are random variables representing the random variation of the RSS caused by shadowing effect and small-scale fading effect respectively. Note that the analysis in this paper allows a general form of the RSS function $P_g(p_t x^{-\eta}, Z, \Omega)$, and the analytical results under the log-normal shadowing model with Nakagami fading (called the Log-normal-Nakagami model) are provided in Section IV as a typical example. Lastly, to be practically meaningful in modeling the RSS attenuation, it is assumed that the RSS $P_g(p_t x^{-\eta}, Z, \Omega)$ is a non-decreasing function of p_t $x^{-\eta}$, Z and Ω respectively.

B. Broadcast Scheme

Suppose that a piece of information is broadcast from an arbitrary node. Once a node receives the information for the first time, it becomes *infectious*. The infectious node holds the information for a fixed amount of time τ_s (called the *sleep time interval*) followed by a random amount of time τ_r (to be described in the next paragraph), then re-transmits the information (to all nodes directly connected to the infectious node) once. Such a *sleep-active cycle* repeats for a fixed number of times, denoted by a positive integer β, after which the node *recovers*. A recovered node stops transmitting the information and will ignore all future transmissions of the same information. The information dissemination process naturally stops (i.e. reaches the *steady state*) when there is no infectious node in the network; and the nodes that have received the information are referred to as the *informed nodes*. It is obvious that the fraction of informed nodes is a key performance metric of information dissemination in a given network.

IV. SIMULATION RESULTS

In [19] Z.Zhang et al proposed analytical and simulation results for percolation probability and the expected fraction of informed nodes. It can be seen that both metrics improve as either of τ_s or σ increases, owing to the reduction of the clustering factor. Our analytical bounds are close to the simulation results as shown in Fig. 1(a), while the discrepancy in Fig. 1(b) is caused by the approximations used in deriving the fraction of informed nodes in [2], which requires another non-trivial analysis to correct.

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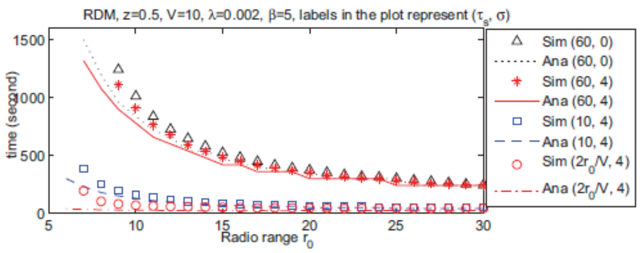

Fig. 1. The delay for a piece of information to be received by 50% of nodes. For the sake of comparison, the value of τs is kept constant while the value of r0 being increased in the first six curves

Fig. 1 shows the time delay for a piece of information to be received by 50% of nodes. It can be seen that the length of the sleeping time interval has a great impact on the delay and our analytical result provides a valid lower bound.

In[20] L.Xiang et al proposed The CDF of aggregate traffic load in a typical PVT cell with different intensity ratios of MSs to BSs based on the Fourier transform of (10a). Fig. 1 indicates that the probability mass shifts to the right with the increasing intensity ratio of MSs to BSs. This is due to the fact that the average aggregate traffic load increases with the increasing value of λ_M/λ_B, i.e., the average aggregate traffic load will increase when there are more MSs in a typical PVT cell.

No.	Percolation probability	Energy and broadcast efficiency	Information dissemination delay
1	$Pc \leq 1+1/RoW(-Roe^{-Ro})$	$Y=Ro/\beta$	less(<)
2	$q=Pr(\lim_{k\to\infty} X(k)\to\infty)$	$Y=Ro/Ro-\lambda\pi r_0^2+1$	Less or equal to(<=)
3	$q_n=Pr(\lim_{k\to\infty} Xn(k)\to\infty)$	$Y=Ro/Ro-\lambda\pi r_0^2-1$	Greater(>)

Table1: comparison of parameters

In[20] L.Xiang shows the results about the energy efficiency of PVT cellular networks with respect to the heaviness index θ and the minimum traffic rate $\rho_{\min}$ at MSs, in which "Num" labels the numerical results and "MC" represents the MC simulation results. First, we fix the values of minimum traffic rate $\rho_{\min}$ at 2 or 3 bits/s/Hz, and analyze the impact of the heaviness index θ on the energy efficiency of PVT cellular networks. Both numerical and MC simulation results consistently demonstrate that the energy efficiency of PVT cellular networks is in-

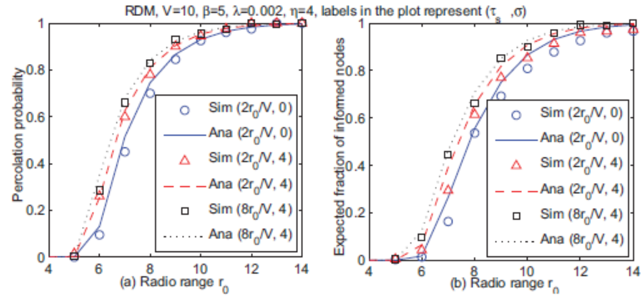

Fig. 2. Analytical (Ana) and simulation (Sim) results for percolation probability and the expected fraction of informed nodes, using different network parameters .Simulation result for percolation probability shows the probability of having at least 10% informed nodes in steady state.

V. CONCLUSION AND FUTURE WORK

In [20] analytical relationship among wireless traffic, wireless channel model and the energy efficiency were shown..In the proposed method,these challenges are tackled by introducing a distributed energy-efficient broadcast scheme taking into account channel randomness for MANETs.

In [19] the speed of information propagation in a mobile network where nodes move independently at random over a square area were verified. Also obtained an upper bound on th flooding time, which is maximum time required for all nodes of the network to be informed. This paper focuses on analyzing the fraction of nodes that can receive the information.

In the future, we are going to investigate the performance of broadcast schemes where the distribution of τr is determined by certain media access control protocols (e.g. CSMA). It is also interesting to investigate the throughput capacity of networks using the proposed scheme, which is also expected to be better than that of networks using traditional epidemic schemes.

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