Modeling and Analysis on a DTN Based Wireless Sensor Network Topology Control

Luqun Li
Department of Computer Science & Technology of Shanghai Normal University, Shanghai, China
Email: luluqun@gmail.com

Abstract—Wireless sensor networks (WSNs) have unlimited and extensive potential application in different areas. Due to WSNs’ work environments and nodes behavior, intermitted network connection may occur frequently, which lead packets delay and lose in the process of data transmission. Most related works on WSNs, seldom consider how to address the issue of intermitted network connection in WSNs. To the best of our knowledge, few papers did related work on how to utilize intermitted network connection to control the topology of WSNs and save the battery of nodes in WSNs. Although intermitted network connection in WSNs is not a good phenomenon, when it occurs, it indeed can keep some nodes in power saving mode. If we can intelligently control WSNs network topology and get intermitted network connection during the intervals of transmission, we will find another way to save the nodes energy to the maximum extent. Based on these ideas, we import the idea of Delay Tolerant Network (DTN) protocol to address the issue. In this paper, first we give the modeling and analysis on node behaviors in DTN WSNs, then we present the end to end performance analysis in DTN WSNs to get the parameters of optimistic hops, maximum hops and each node’s neighbor number, after that we give some basic rules on DTN parameters selection for DTN based WSNs topology control. Finally, we do a related simulation by our DTN based WSNs topology control approach and HER routing algorithm; simulation results show that our approach and algorithm gained better performance in WSN life span, nodes energy equilibrium consumption than DADC.

Index Terms—DTN, Wireless sensor networks, Topology control, M/G/1/K queue, Little’s Law

I. INTRODUCTION

Wireless sensor networks (WSNs) serve as a significant role to bridge the gap between the physical and logical worlds [1]. Nodes in WSNs are tiny embedded devices which only own limited computing ability, data storage space, constrained battery energy and narrow wireless network band width. Among the most critical issues of WSNs is nodes’ energy consumption in general. So, usually, in a WSNs application, to save the battery energy in each node, node can be in power saving model, or in sleeping mode which may lead intermitted network connection and long time delay of transmission even data transmission failure. To address the issue, in former paper we use the idea of delay tolerant network (DTN) protocol and prompted a delay tolerant wireless sensor web service framework (DTN-WSN-WS) as well as performance analysis which partly solved some relate problems[9,10].

Figure 1 DTN-WSN-WS Frame Work.

In recently further study, we found that although intermitted network connection in WSNs is not a good phenomenon in network, when it occurs, it indeed can keep some nodes in power saving mode. For most WSNs applications has some levels real time tolerant specifications constraints (or the maximum time delay tolerant, which is denoted by $T_{QoS}$), for an example, some nodes must send the data to sink node each 10 minutes. To save the battery energy in nodes, during the 10 minutes intervals of data transmission there is no need to keep a network connection. If we can intelligently control WSNs network topology and get intermitted network connection during the 10 minutes intervals of transmission, we will find another way to save the nodes energy to the maximum extent.

Based on these ideas, we import the idea of Delay Tolerant Network (DTN) protocol. In this paper, first we give the modeling and analysis on node behaviors in DTN WSNs, then we present the end to end performance analysis in DTN WSNs to get the parameters of optimistic hops, maximum hops and each node’s neighbor number, after that we give some basic rules on DTN parameters selection for DTN based WSNs topology control. Finally, we do a related simulation by our DTN based WSNs topology control approach and HER routing algorithm; simulation results show that our approach and algorithm gained better performance in WSN life span, nodes energy equilibrium consumption than DADC.

II. RELATED WORKS

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These papers share the common goal of this technique, which is to control the topology of the graph representing the communication links between network nodes with the purpose of maintaining some global graph property (e.g., connectivity), while reducing energy consumption and/or interference. Intermitted network connection should be avoided in topology control.

For the core current communication theory and protocols in WSNs are inherited from traditional wired or wireless network, and the preconditions of related research works are supposed to have at least one route existing from data transmitting source to destination and small delay of transmission. At a given instant time \( t \), a route can be denoted with \( R(t) = \{t \in [0, T] \} \) and \( R(t) = \{t \in [0, T] \} \) where \( n_s \) is the source node, and \( n_d \) is the destination node, and \( S = D \cdot H(t) = t \) denotes the total hops of the route. We use \( R(t) = \{t \in [0, T] \} \) to denote the set of all routes from \( n_s \) to \( n_d \). \( R(t) = \{R(t), R(t), R(t), R(t), R(t), R(t), R(t), R(t), R(t)\} \) .

For most WSNs applications has some levels real time delay tolerant specifications constraints \( T_{QoS} \) which means the maximum delay time from end to end \( T_{QoS} \) is given. In a DTN WSNs, data are handled by “store and forward” approach, intermitted network connection phenomena may occur at any time.

Different from traditional route description above, a route in DTN can be denoted with \( R(t \in [0, T_{QoS}]) \), and \( R(t \in [0, T_{QoS}]) = \{n_s, L, n_d\} \) where \( n_s \) is the source node, and \( n_d \) is the destination node, and \( S = D \cdot H(t \in [0, T_{QoS}]) \) denotes the total hops of the route..
By modeling and analyzing the nodes behavior, we can get the delay time in each node in a route $R_i(t \in [0, T_{005}])$, then we can deduce the total delay time from $n_s$ to $n_d$. $T_i$. To meet the requirement of within delay time of $T_{005}$ for data transmitting, $T_i \leq T_{005}$, then we can get the maximum total hops $h_{max}(t \in [0, T_{005}])$ in $R_i(t \in [0, T_{005}])$ from $n_s$ to $n_d$. $h_{max}(t \in [0, T_{005}])$ is a key parameter in DTN WSNs topology.

In summary, the fundamentally science issues behind DTN topology control for given specific nodes collection in a specific geography space are:

1. How to model and analyze the nodes behavior (for example, node in power saving state or service time of node) in a DTN WSNs, and get the total delay time $T_i$ for data transmitting?

2. For a specific $T_{005}$, how to find the maximum total hops $h_{max}(t \in [0, T_{005}])$ in a route?

3. How to control each node $n_i$’s next hop nodes set $N_i$ to get an optimistic WSNs topology;

In this paper, instead of giving a specific DTN topology control algorithm, we mainly address these three key issues above.

IV. MODELING ON NODE BEHAVIOR

A. Queueing Model for WSNs Node

For a given specific WSNs, node can offer data collecting service, we denoted it with $S_c$. $S_c$ is compositied of two type of services, or $S_c = S_n + S^c$.

$S_n$ is called data service;

$S^c$ is called cache service.

Data in each node may have different privilege levels to be transmitted. For example, if some data is beyond normal distribution region, it may imply some dangerous things happened, and the data should have high privilege to be transmitted. Besides, the user of $S_a$ may be a common user (or other WSNs node) or an administrator, the administrator sends control packet to $S_n$ regulate the work states of $S_n$, while the common user only request for the data from $S_n$ [9,10].

So $S_n$ service can be classified into different privilege levels, to make the problem simple, the users are classified into two classes, or administrators and common users.

Besides, to enhance the throughput of the system and save the battery energy of $S_n$, we also introduce a cache service system $S^c$ to reduce unnecessary repeated request from $S_c$. To analysis the performance of node behavior in DTN we build the following queueing model (See Figure.4)

Queue 1 The first queue is for $S^c$. $S^c$ is only for WSNs cache data packet, WSNs cache system is usually a data search operation, and we use M/D/1/K for this queueing model. The total service request rate is $\lambda$, $S^c$ messages come to $S^c$ queue at the rate of $\lambda$, $P_i$ is probability of getting data from $S^c$. So we can arrive at $\lambda_i = \lambda P_i$. As for this queue is rather easy, we will not go any further. Queue 2 This queue is for $S_n$. This queue is work for both WSNs control and data packet request, as for the service time of $S_n$ is usually with general distribution and it may be in the state of energy saving (node service in vacations states), we use M/G/1/K non-preemptive priority with vacations for this queueing model. Note that the real service is hosted in a WSN node, while the buffer is hosted in $S_n$. All $S_c$ messages are firstly sent to a job scheduling system ($JS$). $JS$ will check the message type and the time stamp to determine which queue the request should be forward to process.

In this model, we assume service request message types are classified in to $n$ priority classes. Messages of each priority class $i(i = 1, 2, K, n)$ arrive according to a
Poisson process with rate $\lambda_i$ and to be served by $S_n$ with a general service time distribution of mean $\overline{X}_i$ and second moment $\overline{X}_i^2$. To make the problem simple, we assume there are two priority classes in our model, the first one is control message, which is usually the control message sent by the administrators or some urgent message request, it comes with the rate of $\lambda_c$; the second one is data message, it comes with the rate of $\lambda_d$. The arrival $\lambda_c$ and $\lambda_d$ are assumed to be independent of each other and service process. All messages comes at the rate of $\lambda_2 = \lambda_c + \lambda_d$. $\lambda_i$ is to be served by $S_n$ with a general service time distribution of mean $\overline{X}_i$ and second moment $\overline{X}_i^2$. $\mu_i$ is its traffic intensity or utilization factor. $\mu_i = \frac{\lambda_i}{\mu_i}$ is the service rate. Then we can deduce the relationship among these parameters above in the followings:

$$\lambda = \lambda_c + \lambda_d, \lambda_i = \lambda_c \cdot \mathbf{g}_1, \lambda_2 = \lambda_c + \lambda_d$$

$$\rho_c = \frac{\lambda_c}{\mu_c}, \rho_d = \frac{\lambda_d}{\mu_d}, \rho_i = \frac{\lambda_i}{\mu_i} = \rho_c + \rho_d$$

$$\overline{X} = \frac{\lambda_c}{\mu_c} \cdot \mathbf{g}_1 + \frac{\lambda_d}{\mu_d} \cdot \mathbf{g}_d$$

$$\overline{X}^2 = \frac{\lambda_c}{\mu_c^2} \cdot \mathbf{g}_1^2 + \frac{\lambda_d}{\mu_d^2} \cdot \mathbf{g}_d^2$$

Another important thing to be noted is $S_n$ may be in energy saving state in a DTN WSNs. In this state $S_n$ does not process any requests. Assume that $V_i, V_2, K$ are the residual of $S_n$’s successive vacation time. The mean of vacation time $V_i, V_2, K$ is $\overline{V}$, and the second moment is $\overline{V}^2$.

B. Performance Analysis on Queue 2

Queue 2 is composed of two queues, one is for control (or urgent) message and the other one is for data message, both queues are M/G/1/K queueing system. Each node may be in power saving state in DTN WSNs, the residual service time $R_i$ in this state can be get by [1]:

$$R_i = \lim_{t \to \infty} \frac{1}{2} \sum_{k=1}^{m} \frac{v_i^k}{2 g_i}$$

For each M/G/1/K, given a block probability of $P_k$, we can the buffer size $K_i$ [3]:

$$K_i = \frac{a \Phi}{2g_i}$$

where $i = c, d$.

$$a = -\ln \left( \frac{P_k}{(1-\rho \cdot P_k \cdot g_i)} \right) + \ln (\rho)$$

$$b = 2 + \sqrt{\rho_i \cdot S_i^2 - \sqrt{\rho_i}}$$

and $S_i^2$ is squared coefficient of variation of the service process. Note that $K_i$ can be hosted on $S_n$. The mean residual service time $R_i$ for all jobs in the queue [12] can be arrived:

$$R_i = \sum_{i=1}^{n} \frac{1}{2} \sum_{i=1}^{n} \frac{\lambda_i \overline{X}_i^2}{2 \cdot \overline{X}_i}$$

So, the total residual service time $R_i$ is:

$$R_i = \sum_{i=1}^{n} \frac{1}{2} \sum_{i=1}^{n} \frac{\lambda_i \overline{X}_i^2}{2 \cdot \overline{X}_i}$$

The waiting time of a job in class $i$ is:

$$W_i = \frac{1 - \sum_{k=1}^{m} \rho_k}{\sum_{k=1}^{m} \rho_k \cdot g_i} \left( 1 - \sum_{k=1}^{m} \rho_k \right)$$

According the Little’s law, the average number of jobs in each class waiting queue is $N_q^i$, and

$$N_q^i = \lambda_i \cdot \mathbf{g}_i = \frac{\lambda_c \cdot \mathbf{g}_1}{1 - \sum_{k=1}^{m} \rho_k \cdot g_i} \left( 1 - \sum_{k=1}^{m} \rho_k \right)$$

The total time that a job spent is $T_i$, and

$$T_i = W_i + \overline{X}_i = \frac{1}{\sum_{k=1}^{m} \rho_k \cdot g_i} \left( 1 - \sum_{k=1}^{m} \rho_k \right) + \overline{X}_i$$

$K_i, N_q^i, T_i$ are very important initial parameters in node behavior in Fig 1. Let $T_t^i$ denotes the maximum tolerant delay time, $P_b^i$ denotes the blocking probability. To guarantee $T_t^i$ and $P_b^i$ constrained QoS, the following prerequisites must exist:

$$N_q^i \leq K_i \& T_i \leq T_t^i$$

Then we can determine the initial parameters in Fig 1, $\rho_i, \lambda_i, \mu_i$ etc. Moreover, for a given specific framework, we can give its performance evaluation by our model as well.
C. Numerical Results and Analysis

To analysis the results that we have deduced above, we give the following initial parameters in the framework: \( \bar{x}_i = 0.01, \sigma^2 = 0.02, \bar{x}'_i = (\bar{x}_i)^2 + \sigma^2_i; \bar{V}_i = 0.001, \sigma_V^2 = 0.01, \sigma^2_V' = (\bar{V}_i)^2 + \sigma^2_V, \lambda_i = 0.1\lambda, \) we get \( p_k - \rho \) - Buffer Size Relationship. \( \rho \)

According to the equation (2)(3)(4)(5), by increase the value of \( \lambda \), we will also get increased traffic intensity of the system \( \rho \), the we can get the queue size and wait time of each message with different priority, see Figure.6 and Figure.7.

\[ \text{Figure.5} \quad p_k \cdot \rho \cdot \text{Buffer Size Relationship} \]

\[ \text{Figure.6} \quad N_c \text{ and } N_d \text{ with } \rho \]

\[ \text{Figure.7} \quad W_c \text{ and } W_d \text{ with } \rho \]

Fig.6 shows that with the increasing of \( \rho \), \( W_c \) will also increase, but the wait time will be below than 1.4 second; while \( W_d \) will increase very fast, and the wait time will below 84 second. Given a specific \( k_i \) and \( T_i \), we can roughly get the range of \( \rho \), for the service time \( \mu_i \) usually is known, then we can regulate \( S_{c} \)'s rate \( \lambda \) to get the QoS guaranteed service.

V. END TO END PERFORMANCE FLOW ANALYSIS

In a DTN WSNs, data is stored and forwarded by nodes along a path from source to destination. To guarantee bounded delay end to end with zero packet loss, we use Stop-and-GO queueing as deterministic bounds (See Fig.). Stop-and-GO queueing was prompted by Go lestani 13. The Stop-and-GO queueing rules in our model are stated as follows:

1. Packet in incoming “Bundles” \( F' \) and \( F'' \) are stored at node \( A \), and cannot be forwarded until the beginning of the outgoing “Bundles” \( F' \) following completion of “Bundles” \( F' \) and \( F'' \) respectively.

2. A node should not stay idle or in pore is any eligible “Bundles” in the queue.

The total delay \( D_\rho \) end-to-end, for any packet by Stop-and-GO queueing is bounded by [13]:

\[ (m-1)\bar{g}_1 + \tau^k \leq D_\rho \leq (g mn+1)\bar{g}_1 + \tau^k \quad (7) \]

Where, \( m \) is the hops of the route, \( g = 2, T_i \) in equation(5) is the total time that a job spent in a node, \( \tau^k \) is propagation delay which is determined by the transmitting technology that use in WSNs. For example, \( \tau^k \) in a Zigbee WSNs is great then that in a Wi-Fi WSNs.

To meet a specific \( T_{QoS} \), the up bound in equation (7) must small than \( T_{QoS} \), i.e.

\[ (g mn+1)\bar{g}_1 + \tau^k \leq T_{QoS} \]

Then we get the hops in the transmitting route is bounded by:

\[ m \leq \frac{T_{QoS} - \tau^k - T_i}{g \bar{g}_1} \quad (8) \]

The lower bound of \( m \) is denoted by \( \lfloor m \rfloor \), and the
maximum total hops $h_{\max}(t \in [0, T_{QoS}])$ in a route must meet:

$$h_{\max}(t \in [0, T_{QoS}]) = \lceil m \rceil = \left\lceil \frac{T_{QoS} - \tau^k - T_i}{g g^1} \right\rceil$$  \hspace{0.5cm} (9)

Equation (9) mean for any route $R_i$ from source node $n_s$ to $n_g$, $h_i \in [1, h_{\max}(t \in [0, T_{QoS}])]$.

To evaluate equation (9), we give the following initial parameters $T_{QoS} = 1000$ time unit, $\tau^k = 1$ time unit; we get the relationship of $h_{\max}$ against $T_i$ in Figure. Fig shows that with $T_i$ increasing $h_{\max}$ drops rapidly.

VI. WSNs TOPOLGY CONTROL

A. WSNs Node Energy Model

In this paper, we assume a simple model for the radio hardware energy dissipation where the transmitter dissipates energy to run the radio electronics and the power amplifier, and the receiver dissipates energy to run the radio electronics, as shown in Figure.1. Power control can be used to invert this loss by appropriately setting the power amplifier—if the distance is less than a threshold $d_0$, the free space ($FS$) model is used; otherwise, the multipath ($MP$) model is used [14-17].

![Figure 9: Data Transmitting in A DTN WSNs](image)

For the data sending nodes in WSN, to transmit a $k$-bits message to a distance $d$, the energy consumption model is:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-mp}(k,d)$$

$$= \begin{cases} 
  k g_{elec} + k g_{mp} g_{1}^{2}, & d < d_0 \\
  k g_{elec} + k g_{mp} g_{1}^{4}, & d \geq d_0 
\end{cases}$$

Where, $E_{elec}$ is the electronics energy, it depends on factors such as the digital coding, modulation, filtering, and spreading of the signal, as for the amplifier energy, $E_{tx} g_{1}^{2}$ or $E_{mp} g_{1}^{4}$, it depends on the distance to the receiver and the acceptable bit-error rate.

For the data receiving nodes in WSN, to receive this message, the energy consumption model is:

$$E_{Rx}(k) = E_{Rx-elec}(k) = k g_{elec}$$

B. The Determination of Optimistic Hops $h^*$

From a global view, each node’s neighbor nodes should be determined by hops from source node to sink node and the distance of each hop.

Reference provided the optimistic hops $h^*$ from node $n_i$ to sink node $n_{sink}$ and the average distance $D$. In addition, it also gave corresponding analysis and proof.

The optimistic hops from source node to sink node $h^*$ is determined by:

$$h^* = \left\lfloor \frac{D}{d_c} \right\rfloor \text{ or } \left\lceil \frac{D}{d_c} \right\rceil$$  \hspace{0.5cm} (10)

Where, $d_c$ is a variable that has not with $D$, and

$$d_c = \gamma \frac{\alpha_1}{\alpha_2} (\gamma - 1).$$

$$\gamma = \begin{cases} 
  2 & (d \leq d_0) \\
  4 & (d > d_0) 
\end{cases}$$

$$\alpha_1 = 2 g_{elec}$$

$$\alpha_2 = \begin{cases} 
  \epsilon_{mp} (d \leq d_0) \\
  \epsilon_{elec} & (d > d_0) 
\end{cases}$$

We assume each node’s geographic location in WSN is known, so $D$ can be determined, and $d_c$ can also be determined, so we can arrive at $h^*$.

To meet the QoS requirement in DTN WSNs $h^*$ must be bounded by the following inequality:

$$h^* \leq h_{\max}(t \in [0, T_{QoS}]),$$

$$h_{\max}(t \in [0, T_{QoS}]) = \lceil m \rceil = \left\lceil \frac{T_{QoS} - \tau^k - T_i}{g g^1} \right\rceil$$  \hspace{0.5cm} (1)

(1). When we calculate $h^*$ by equation (10), if we find $h^* \leq h_{\max}(t \in [0, T_{QoS}])$, we can get the right optimistic hops $h^*$.

(2). When we calculate $h^*$, and only to find
h^* > h_{\text{max}} (t \in [0, T_{QoS}])\), we can regulate the value $T_i$ in equation (5) and the value $R_q$ in equation (1) by adjusting the node in power saving distribution time (or node service in vacation time), decrease the value $T_i$.

According the relationship between $T_i$ and $h_{\text{max}} (t \in [0, T_{QoS}])$ in equation (9) and Figure.7, we can get the increased value of $h_{\text{max}} (t \in [0, T_{QoS}])$, until $h^* = h_{\text{max}} (t \in [0, T_{QoS}])$. Eventually we can get the right optimistic hops $h^*$.

C. The Determination of Neighbor Node Numbers

Considering making equilibrium energy consumption, we give our model to determine the diameter $\phi$ of each node’s communication scope:

$$\phi = \left( \frac{E_{\text{elec}}}{E_{\text{mp}}} \right)^{\psi} d_i^\psi d_0^{1-\psi}$$

where $E_i$ is node $n_i$’s energy; $d_i^\psi$ is the distance from node $n_i$ to the sink node $n_{\text{sink}}$; $d_0$ is a consent for a given WSN node; $\overline{E} = \frac{1}{n} \sum_{i=1}^{n} E_i$ is the average energy of a WSN; $\overline{D} = \frac{1}{n} \sum_{i=1}^{n} d_i^{\psi}$ is the average distance from $n_i$ to $n_{\text{sink}}$. $\sigma$ is a parameter to be determined. It has something with the energy left in each node.

As for $n_i$’s neighbor node numbers $|N_i^\psi|$, $|N_i^\psi|$ is with the data traffic and the bandwidth of WSN.

For a given loss probability of $\varepsilon$, and bandwidth $B$, and the probability $p$ that each neighbor node sending data to node $n_i$, the maximum $|N_i^\psi|$ can be determined by equation.5.

This issue is a typical call admission control (CAC) problem, we can just use the conclusion and get $|N_i^\psi|_{\text{max}}$.

$$|N_i^\psi|_{\text{max}} = \frac{B}{p} - \frac{1}{p} \left[ \sqrt{4\psi(C + \psi) - 2\psi} \right]$$

where: $\psi = k^2 (1-p) / 4$,

$$k = \frac{1}{\ln(2\pi) - 2\ln\varepsilon}$$

By determining (1) (2) (3), we can roughly be determine the topology of a WSN.

D. Summary on DTN WSNs Topology Control

For a give specific WSNs QoS data transmitting requirement ($T_{QoS}$ is known), we can theoretically adjust the node power saving distribution time and get $h_{\text{max}} (t \in [0, T_{QoS}])$ in equation (10) as well as each node’s neighbor node numbers in equation (11).

VII. RELATED SIMULATION WORK

To verify our modeling and analysis above, we set up a simulation. There are 200 nodes in it. The nodes are distributed randomly in a square in 680m × 530m; the sink node is in the center of the square. Each node initial battery energy is randomly distributed between 2~3J, we neglect the affects of sign bump and interference [11,12].

In our simulation, we assume that the life span of a WSN is over when 20% of nodes in the WSN used up their battery energy[12-25].

### Table.1 The Initial Parameters in Simulation

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum transmitting distance $d_{\text{max}}$</td>
<td>100m</td>
<td></td>
</tr>
<tr>
<td>Broadcast package size</td>
<td>$\text{Broad message}$</td>
<td>20bits</td>
</tr>
<tr>
<td>Data package size</td>
<td>$\text{Data message}$</td>
<td>300bits</td>
</tr>
<tr>
<td>Transmitter/receiver energy</td>
<td>$E_{\text{elec}}$</td>
<td>50nJ/bit</td>
</tr>
<tr>
<td>Radio amplifier energy</td>
<td>$E_{\text{mp}}$</td>
<td>0.0013pJ/bit/ m^2</td>
</tr>
<tr>
<td>Character Distance</td>
<td>$d_c$</td>
<td>100m($\gamma = 2$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>71m($\gamma = 4$)</td>
</tr>
</tbody>
</table>

We get the following DTN WSNs topology of the WSN,

![Figure.11 The DTN Topology of the WSNs](image)

In addition, we use algorithm HER routing algorithm. When the WSN span is over, we use our algorithm HER can send data 2500 times, while use DADC, we can only send data 1124 times. Figure.12 is the distribution of nodes’ energy left when the WSN’s life span is over by using HER algorithm. Figure.13 is the distribution of nodes’ energy left when the WSN’s life span is over by using DADC algorithm. Figure.14 is the statistics on the nodes energy left when the WSN is dead.
do end to end performance analysis in DTN WSNs and get much precise $h_{max}(t \in [0,T_{Q5}])$ for topology control.

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Luqun Li is a professor in Computer Department of Shanghai Normal University. His main research interests are computer networks, wireless communication.

Email: liluqun@gmail.com
Mobile Phone: +86-13671988511