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MODEL BASED APPLICATION LEVEL MIDDLEWARE FOR DESIGN OF WIRELESS SMART CITY

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Abstract- The Wireless Smart City (WSC), an emerging concept in Smart Grid and Internet of Things, has attracted an increasing number of customers and developers - based with its promise of low cost implementation and flexibility. At the same time, the challenges faced with in the field applications hinder the progress of WSC from researches into commercial production. A model based application level auxiliary platform is presented to help the development of WSC. This middleware together with the existing network simulators replace field test during WSC design. The proposed platform reduces engineering cost and increases development efficiency. Network optimization is implemented to provide an automatic design of WSC.

Index terms: Smart City, Performance Evaluation, Optimal Deployment, Simulated Annealing, Wireless Sensor Network

I. INTRODUCTION

The Wireless Smart City (WSC) is one of the important components in Smart Grid and Internet of Things, attracting increasing attentions in the engineering field [1] [2]. With the advantage of distribution information aggregation and remote device management provided by thousands of sensors and controllers [3] [4], potential challenges for the system design (such as large scale of network, limited resources, sensor heterogeneity, unreliability of changing topology, and data delay) are emerging as well. Field test provides an effective way for designers to accurately evaluate the whole system and gives powerful verification for the subsequent improvements. Nevertheless, this method also spends huge amounts of engineering costs and retards the progress of WSC design, especially in the network of large scale or the complex geographical environment. More green technologies are required to realize the same function of field test in the network design.

With the development of computer-aided simulation technology, an increasing number of field tests are replaced by this method. A WSC design will be firstly tested in the computer by modeling the specific application. This kind of method is widely applied in variable applications which can highly reduce engineer cost as well as accelerate development efficiency. However, the most existing protocol level simulators are designed for the professional soft engineers major in the communication field, including OPNET, NS2, and OMNET+ [5] [6]. The experts in the other domains are difficult to master the usage just within a short training. And no suggestion can be acquired from the simulation because no optimization algorithm is included in the simulator. Thus, the existing simulators are not able to perfectly take place of field test in WSN applications [7]. The development of simulators aimed to the specific field applications should take a long cycle and lack of universality.

In this paper, we propose a model based application level auxiliary platform for WSC design. It is a middleware between the real scenario and the existing simulator considering the complete application condition, and possessing a friendly user interface to simplify using difficulty for designers. To guarantee accurate and reliable evaluation of the real scenario, key information of WSC system should be abstracted by various models provided in the model libraries and translated into source files implemented in the corresponding simulator via the proposed platform. Furthermore, the system design is able to be automatic optimized according to the designer requirements input into the platform. With the help of this kind of middleware, simulation of the real scenario becomes easy to be implemented for not only the software engineers but also the domain experts in other fields.

The organization of the lecture is as follows. After a general introduction of the necessary of common application simulation tools, the architecture of the proposed platform is presented and its components are introduced in detail in the next section. The models included in this platform are respectively described in Section III. Section IV gives the principle and the algorithm of network optimization. In Section V, the simulation environment, an example of real WSC, is firstly provided. As well, the performance evaluation and optimal deployment are given in this section. Finally the conclusion is given in Section VI.

II. PLATFORM ACHITECTURE

a. Overview of the proposed platform

Performance evaluation is an important process during the design phase of WSC, which is closely related to the hardware architecture of physical nodes as well as the geographical environment of real scenario. Just a small change in physical feature of node or geographical environment can bring about a big difference of evaluation result or even the completely changing of them. Furthermore, computer aided tests implemented by different simulators focus on the different aspects of performance evaluation [5], [6], [8].

What we proposed is to make the process of performance evaluation and optimization as general as possible, which means that the platform is designed separated from the architecture (physical node or geographical environment) of specific scenario. Model abstraction is a good solution to address this requirement. The objects in WSC (e.g. node, protocol, space interface, user traffic, and network deployment) are abstracted and stored in the model library in specific forms. The execution of simulation is independent on the poetries of system objects. Using friendly user interface, designer inputs the attributes of node (hardware and software parameter), protocol and network (network deployment, space interference, and user behavior). Unified form of data is exploited in the execution mechanism and transformed into the specific code source files for different simulators. Different translation rules are provided to meet the input requirements of various simulators. Model libraries and translation rules are able to be modified via the user interface which makes the platform easy to be improved for the new applications. Figure 1 shows the function of the proposed platform closely related to the designer, the WSC application and the simulator. Network Optimization is the core of the proposed platform differed from the other simulators.

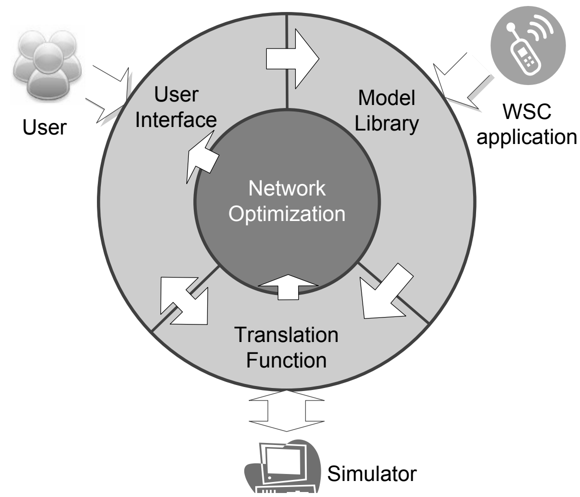


Figure 1. Functional view of the proposed platform

b. Platform Architecture

This proposed platform takes into account from three levels:

b. i Physical node

There are huge amounts of various physical wireless devices existing in the commercial market, including the products of TI, Atmel, and Philips. Node library is an important component in the platform providing the realistic simulation of node behavior in real scenarios. Designer can use these models to build virtual nodes by inputting the required attributes.

b. ii Protocol algorithm

Communication Protocol is a necessary component of the network establishment. Since huge amounts of codes require a lot of time to execute simulation which is not suitable in field application. A simplified model of protocol algorithm is provided to describe the behaviors in different communication layers, including the processing of messages, the state jumping in each layer and the error handling.

b. iii Network architecture

Geographic environment is closely related to the network performance in wireless communication. Node deployment (defining the node models used in the network, including node position, node type, and so on), space distribution (the obstacle position and the signal attenuation through obstacle), and user operation (inter-arrival time, operation number, and user number) can make huge amounts of impacts on network topology and communication efficiency.

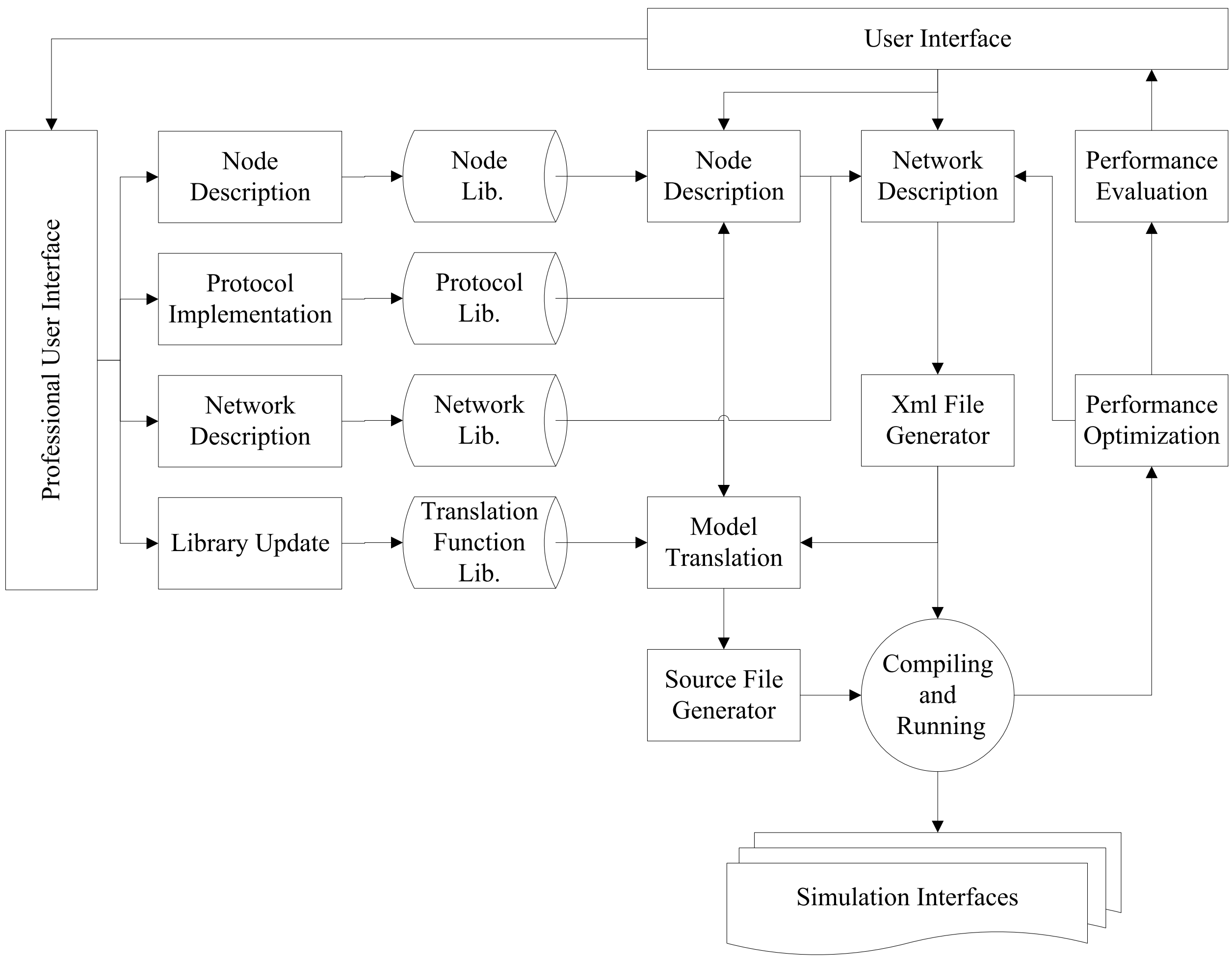


Figure 2. The architecture of the proposed platform

Figure 2 shows the architecture of the proposed platform and its components. All objects in real scenario are transformed into the virtual models in the platform via model libraries of node, protocol, and network. The data inputting is executed by designer through calling these models in the user interface. Translation function modules and XML file generator provide the important access to simulation by translating the data into the source files for the corresponding simulators. Multiple translation rules suitable for different simulators are included in the translation function library. Performance optimization module provides the modification scheme of the network deployment and determines the optimization effects from the simulation results. All the network evaluation and optimization results are able to be shown in the user interface.

III. MODEL LIBRARY

Model library is the most important component supporting the simulation of real scenario. According to analysis of key factors in WSC, four kinds of models (i.e. node model, protocol model, network model, and translation function) are required in the platform to describe various application scenarios or connect different simulators.

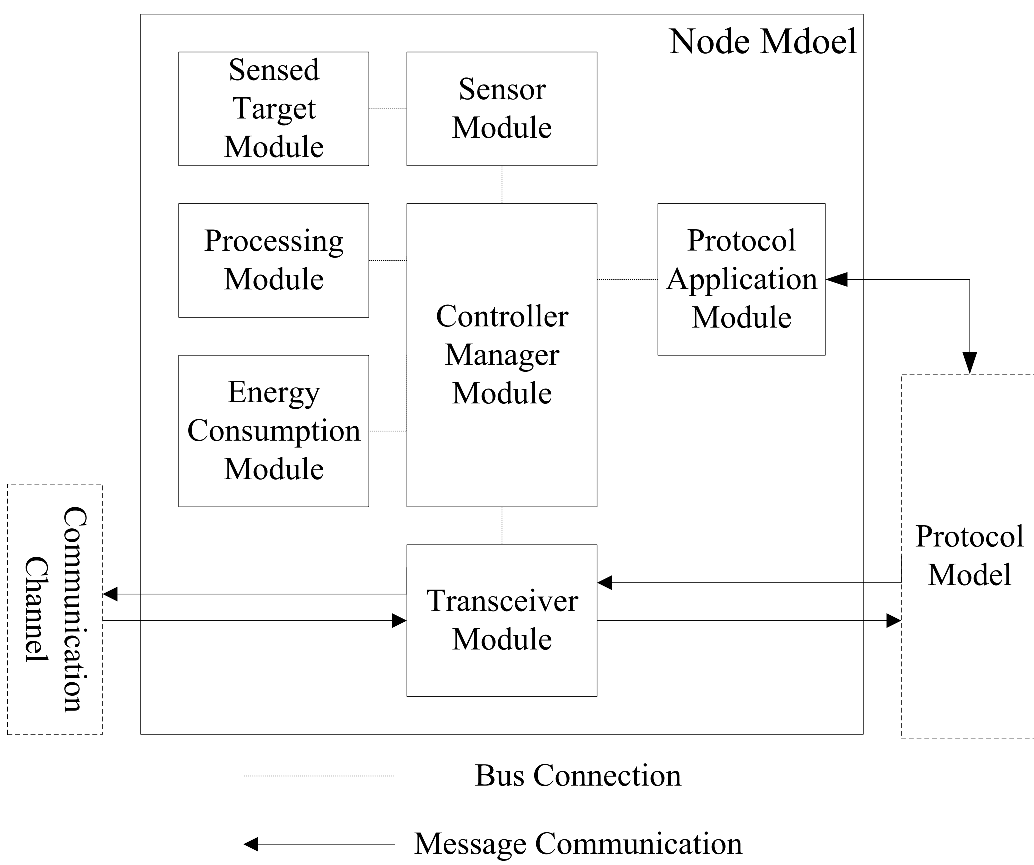


Figure 3. The architecture of node model

a. Node Model

Node model takes into account both hardware and software aspects of an individual sensor device. All the modules in a node can communicate directly (physical link) or by message. Figure 3 shows the node architecture. Protocol model is separated from node model because of its great impact on the performance evaluation.

b. Protocol Model

Protocol model is a description of the communication protocol applied in the sensor node. The communication protocol can be classified into several layers according to the OSI model. The protocol layers included in different protocol standard are not the same. Figure 4 shows the protocol model of IEEE 802.15.4/ZigBee, a common local wireless communication protocol used in WSC. In this model, only three layers are referred to including Network layer, MAC layer and Physical layer.

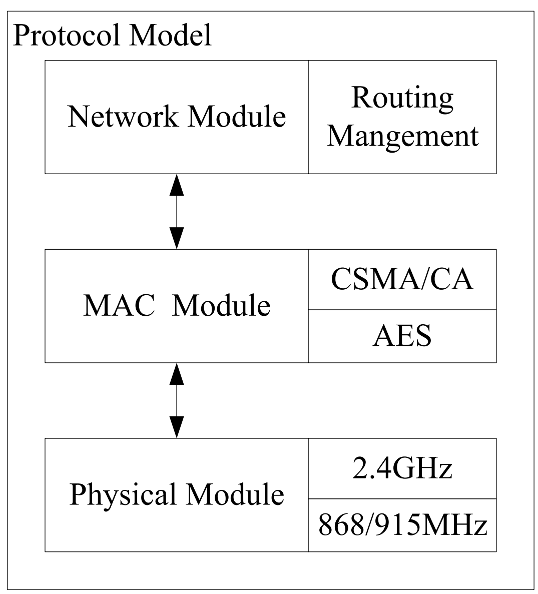


Figure 4. The architecture of protocol model

c. Network Model

Network Models describe various parameters in geographical environment, including:

- Node deployment: the position and type of node are related to the target network which will be different from physical architecture of the individual node. This information is defined in the network model as a part of network deployment.
- User Operation: user operations include operation interval, operation number and user number, which are related to users in the target network.
- Space Distribution: obstacle interference is the important impact of signal propagation. The location and interference degree of obstacle should be abstracted as the components of network model.

Network model is represented by XML schema shown in figure 5 in order to generate a source code file according to the simulation requirement.

```
<network>
    <identification>
        <type></type><name></name><id></id>
    </identification>
    <characteristics>
        <node>
            <!...Import XML description of node…>
            <dimension> </dimension><type></type>
        </node>
        <obstacle>
            <dimension></dimension>
        <type></type><value></value>
        </obstacle>
    </characteristics>
    <behavior>
        <condition>
            <source_id></source_id><destination_id></destination_id>
            <frequency></frequency><op_num></op_num>
            <user_num></user_num>
        </condition>
    </behavior>
</network>
```

Figure 5. The XML schema of network models

In these models, the radio propagation factor is the most interesting focus in the discussion of space distribution which is the biggest uncertain impact factor in all the field applications [7] [9]. As wireless radios have very tight constraints on power and bandwidth, lowering the limits on transmission power and signal attenuation is the best way to guarantee the system reliability.

Attenuation through space obstacles must be considered in order to present a realistic model of communication channel with multiple obstacles in the simulation. Here, we give the examples of radio propagation considering air attenuation, space obstacle attenuation factor and interior decoration attenuation factor, respectively. A kind of semi-empirical algorithm is used during the course of channel modeling.

In free space, the power reaching the receiving antenna, which is separated from the transmitting antenna by a distance *d*, is given by the Friis free-space equation:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \tag{1}$$

where G_t and G_r are the gain of the transmitting and the receiving antenna, respectively. P_t and P_r are the transmitted and received power, respectively. L is the system loss factor, not related to propagation. λ is the wavelength in meters. Path loss (PL) can be defined by [9], [10]

$$PL[dB] = 10\log\frac{P_t}{P_r} \tag{2}$$

In the real wireless channel, free space is not the appropriate medium. A general PL model uses a parameter, γ, to denote the power-law relationship between the separation distance and the received power. So, path loss can be expressed as [9], [11]

$$PL(d) = PL(d_0) + 10\gamma\log\left(d/d_0 \right) + X_\sigma \tag{3}$$

where d_0 is the received-power reference point. X_σ denotes a zero-mean Gaussian random variable of standard deviation σ. $\gamma=2$ characterizes free space. However, γ is generally higher for wireless channels. In the villa, γ is measured as 2.74.

The floor and wall attenuation are seen as a mean path loss exponent that was a function of the number of floors or walls between source and destination [11]. If the distance between source and destination is much larger than the thickness of floor or wall, the factor of angle should be neglected. The path loss then takes the form [9]

$$PL(d)[dB] = 10\log(d/d_0)^\gamma + \sum_{p=1}^{P} SPAF_W(p) + \sum_{q=1}^{Q} SPAF_F(q) + \sum_{s=1}^{S} SPAF_G(q) \tag{4}$$

where P, Q, S are the number of walls and floors, respectively. $SPAF_W$, $SPAF_F$, $SPAF_G$ are the attenuation factor of wall, floor, and glass partition, respectively. These three factors can be calculated from the measurements.

The analysis of interior decoration attenuations is similar to that of space partition attenuations. The only difference is that the impact factor of radio propagation angel can not be neglected because of the irregular shape of the decoration object. The path loss then is expressed as

$$PL(d)[dB] = 10\log(d/d_0)^{\gamma} + \sum_{p=1}^{P} IDAF(p)/\cos(\theta) \tag{5}$$

where θ is the angle. IDAF is the attenuation factor of interior decoration. Considering that angel is related to the position of source and destination. The path loss also can take the form

$$PL(d)[dB] = 10\log(d/d_0)^{\gamma} + \sum_{x_s,y_s,x_d,y_d} IDAF(x_s,y_s,x_d,y_d) \tag{6}$$

Where x_s, y_s, x_d, y_d are x and y positions of source and destination, respectively.

The case of continuous even distributed objects is specially considered in the RPM which requires a huge amount of calculations. According that the distance between any two objects is a constant, the attenuation through this kind of object array can be seen as the function of the distance interval *d*. The PL model with object array attenuation factor is

$$PL(d)[dB] = 10\log(d/d_0)^{\gamma} + \sum IDAF(d,\theta) = 10\log(d/d_0)^{\gamma} + \frac{d}{D}\sum IDAF_{avg}(\theta) \tag{7}$$

d. Translation Function

Translation function is aimed to provide an application interface for the simulators. As the types of source files in various simulators differ from one another, a library is necessary in the platform to make it easy to connect with these different simulators. Translation rules are included in library aimed to the corresponding simulator and may modified by the professional users with the change of simulator.

IV. OPTIMIZATION OF NETWORK DEPLOYMENT

a. Performance Evaluation Metric

As the proposed platform is designed for field application, no complex performance evaluation metrics are commended in it. Simple and direct evaluation conclusions are pursuit by the field experts not major in the communication field. An evaluation metric, named *RCT*, is provided in this section in order to quickly estimate the performance of WSC in which reliability and timeliness are the two important requirements of control system. *RCT* is measured in terms of the network reception rate, to estimate performances of the whole system. The network reception is defined how many percentage of packets sent can be received correctly and timely. In this definition, there are three conditions of packet reception: the first one is that the packet must arrive at the destination; the second one is that the received packet should be correct; and the third one is that the arrival time is less than the threshold value. In general, system fault in process of data exchange in WSC can be divided into two types: transmission failure and reception out of time. Transmission failure means that the packets are dropped by senders or routers. And reception out of time means that the arrival time of packet is larger than the threshold value. In the following, the arrival time threshold is set as 0.05s, which means that the packet arriving beyond 0.05s is seen as the reception out of time. $Pr_{timeout}$ is defined as the probability of timeout reception, which can be expressed as

$$\Pr_{timeout} = \Pr\left(T \le t \le T_S\right) = \frac{\int_{t=T}^{T_S} r_{recv}\left(t\right)}{\int_{t=0}^{T_S} r_{recv}\left(t\right)} = \frac{\int_{t=T}^{T_S} Packet_{recv}}{\int_{t=0}^{T_S} Packet_{recv}} = 1 - \Pr_{timely} \tag{8}$$

where T is the arrival time threshold. T_s is the simulation time. $r_{recv}(t)$ is the packet sending rate. $Packet_{recv}$ is the packet number received by destinations in each time unit. Pr_{timely} is the timely reception rate. And $Pr_{failure}$ is defined as the probability of sending failure, which can take the form

$$\Pr_{failure} = \Pr\left(T_S < t \le \infty\right) = \frac{\sum Packet_{sent} - \sum Packet_{recv}}{\sum Packet_{sent}} = 1 - \Pr_{correctly} \tag{9}$$

where $Packet_{send}$ is the number of packets expected to be sent to the destinations at a time unit. $Pr_{correctly}$ is the correctly reception rate.

As the independence of these two failures, RCT can be expressed as

$$RCT = \sum_{i=1}^{n} \Pr\left(A_i\right) = \left(1 - \Pr_{timeout}\right) \times \left(1 - \Pr_{failure}\right) \tag{10}$$

b. Optimization algorithm

Optimization of network deployment is the obvious advantage of the proposed scheme providing automatic regulation and judgment. It is aimed to trace a kind of network deployment in line with the user requirements through some optimal algorithms. Designers have to firstly define the constraint conditions in the user interface, and then the deployment will be auto-adjusted to meet these conditions. Various sensitive variables exist in field application to impact performance evaluation and increase optimization difficulty, in which remote control number, user operation, and node location are all the attractive impact factors changing at any time.

$$\begin{aligned} \max \quad & Var_{sen}, \\ \text{s.t} \quad & R_S\left(Var_{sen}\right) \geq R_{TH}, \\ & Var_{senMIN} \leq Var_{sen} \leq Var_{senMAX} \end{aligned} \tag{11}$$

where Var_{sen} is the sensitive variable, Var_{senMIN} and Var_{senMAX} are the minimum and maximum value of the sensitive variable. R_{TH} is the threshold of *RCT* defined in different fields.

In the first time, we select Simulated Annealing (S.A.) to implement the network optimization which is based on an iterative improvement technique, suitably corrected introducing random moves [14]. A generation and an acceptance procedure for the different network configurations must be introduced during the process of such an algorithm, or, better, a perturbation method has to be defined allowing to pass from one configuration to another. The acceptance criterion is managed by a random number generator and a control parameter, called temperature.

```
Procedure TSPSA:
begin
    init-of-T; { T is the initial performance value set by the designer}
    S={1，……，n}; {S is the initial deployment, a random optional location is selected}
    termination=false;
    while termination=false
    begin
      for i=1 to L do
      begin
        generate(S'form S); { select a different optional location to generate a new deployment S'}
        ΔC:=f(S'))-f(S);{f(S) is the performance of current deployment}
        if (ΔC<0) OR (exp(-ΔC/T)>Random-of-[0,1])
           S=S';
        if the-halt-condition-is-TRUE THEN
            termination=true;
        end;
        T_lower;
      end;
    end
end
```

Figure 6. The pseudo-code of optimization procedure

Figure 6 illustrates the pseudo-code of the S.A. procedure in node location optimization. The search strategy starts from an admissible solution of the problem and then continues in the neighborhood of such a solution. It should be more intensive in the more promising regions and avoiding the searches that move far from these regions but accepting with certain probability, also searches that worsen the solution. Slowly modifying of the temperature T drives the system toward the final solution, which corresponds to a local minimum of the objective function. Metropolis algorithm is the core of this procedure. The value of exp($-\Delta C/T$) is a number in [0,1] when ΔC and T are positive, which may be correctly understood as a probability dependent on ΔC and T . The cooling ratio of T represents the number of iteration executed for each value of the temperature, i.e., the length of the Markov chain in the Metropolis algorithm.

V. SIMULATION RESULTS AND ANALYSIS

a. Simulation Environment

In this paper, we use this proposed platform to test the scenario of a 3-theroy villa building. A home WSC is equipped in a villa which is composed of 34 wireless nodes. The structure of villa building incorporating $300m^2$ of living space brings the growing number and type of device nodes and space obstacles to complicate the network topology and increase the space interferences. The size of each storey is $12m\times8m$ and the height is $3m$. There are 3 bedrooms, 3 living rooms, and some other functional rooms in the villa, in which 6 persons are assumed to live. Devices in WSC are classified into sources and destinations. There are 4 thermostats and 8 remote controls in the villa which are two kinds of sources. Each thermostat transmits one packet to its destination every $60s$. The remote control is set to transmit traffic according to the Poisson distribution or the constant distribution with different operation intervals and the lower limit of $100ms$ is obtained from the hardware information. The detailed parameters of all user operations in the villa are listed in Table 1.

IEEE 802.15.4/ZigBee (unslotted CSMA/CA mode) is selected as the communication protocol in this WSC is. The simulator selected in this section is OPNET Modeler. Compared field test is implemented in the testbed of TI CC2430.

b. Performance Evaluation and Optimization

We choose *RCT* as the metric in this lecture to comprehensive evaluate the performances of control and sensing in the WSC. *RCT* is defined as the packet number received correctly and timely by the sink node per second. The sensitive variables of sending frequency per source, source number, and node position are discussed in this section.

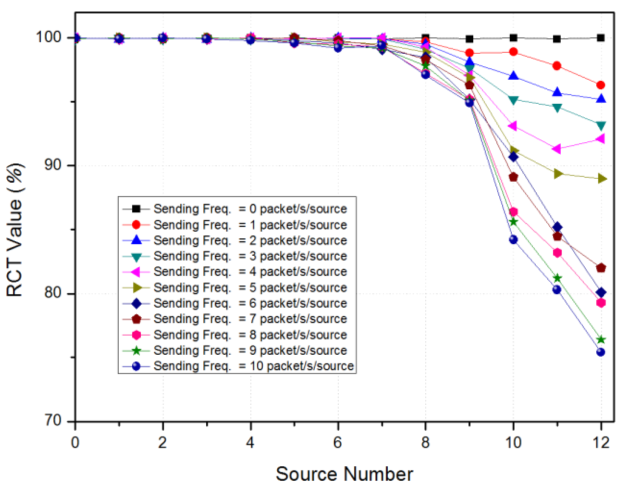
Table 1: Parameter Settings of user operations

Source	Destination	Operation Interval (s)
G1	A1, C1, D1	≥0.1
H1	B1, E1, F1, J1	≥0.1
I1	J1	60
K1	J2, L2, N2, G3, I3	≥0.1
G2	A2, C2, D2, E2, J2	≥0.1
H2	B2, C2, D2, F2, L2	≥0.1
I2	J2	60
K2	L2	≥0.1
M2	N2	≥0.1
E3	A3, B3, C3, D3, G3	≥0.1
F3	G3	60
H3	I3	60

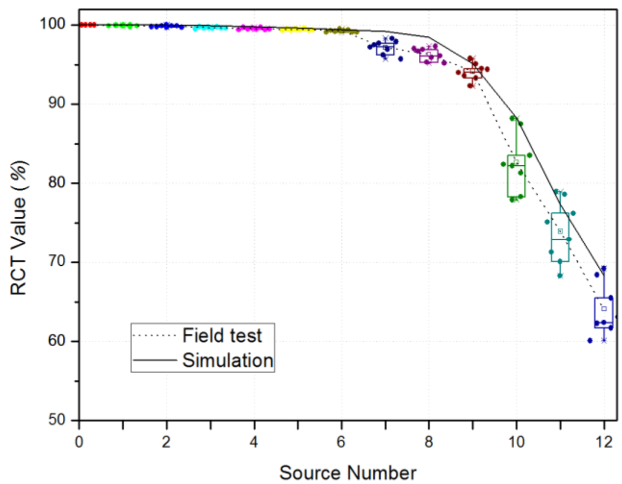
b. i Discussion on variable of source number

The number of traffic created by source nodes directly impacts the network load. The worst case is that all the source nodes deliver packets at the same time. How many source nodes are allowed to send control commands at one time should come into view.

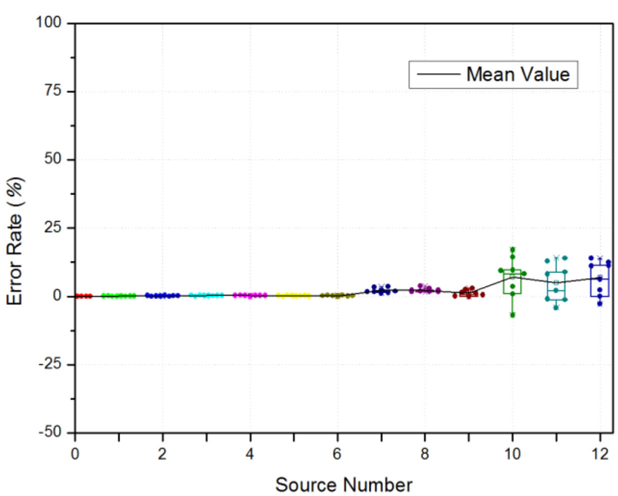
Figure 7(a) shows the continuous decreasing trend of *RCT* with the growing source number at the range of sending frequency from 0*packet/s/source* to 10*packet/s/source*. When source number is larger than 4 and sending frequency is larger than 2 *packet/s/source*, MAC contentions are brought about and enhanced with the increasing source number causing packet losses. Otherwise, all the traffic can arrive at the determination timely with no error which means the value of *RCT* can be kept as 100%. Figure 7(b) illustrates the comparison between field test and simulator in the case of 2 packets transmission per second per source. The results of field test are changed on the same trend of that obtained from the proposed scheme. The error rate of simulation in this case is shown in figure 7(c), the maximum value of which is within 7%. When the source number is large, the error rate is promoted because of the incomplete modeling of MAC contentions. It is required to be improved in the next work. Figure 7(d) shows the optimization tracing of source number when sending frequency is kept as 2*packet/s/source*. The maximum number of optimization step is set as 6. The target *RCT* is set as 99%. The halt condition is that the number of outside loops is larger than that of optional locations. And the optimal value of source number is 6 which is Metropolis accepted by S.A. algorithm.



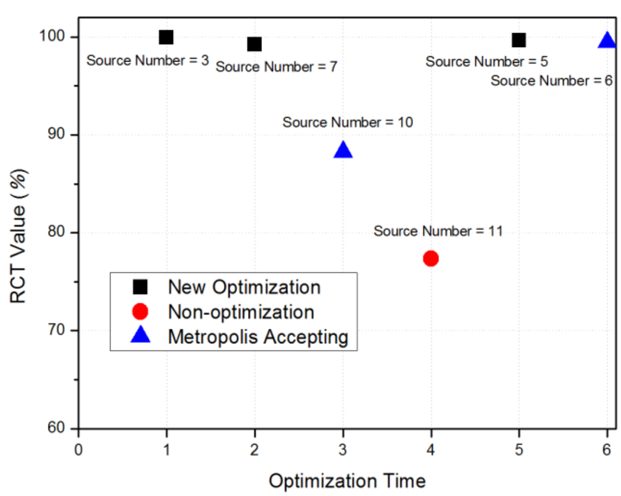
(a) *RCT* with variable sending frequency (0~10 *packet/s/source*)



(b) *RCT* comparison between field test and simulation when sending frequency is 2*packet/s/source*



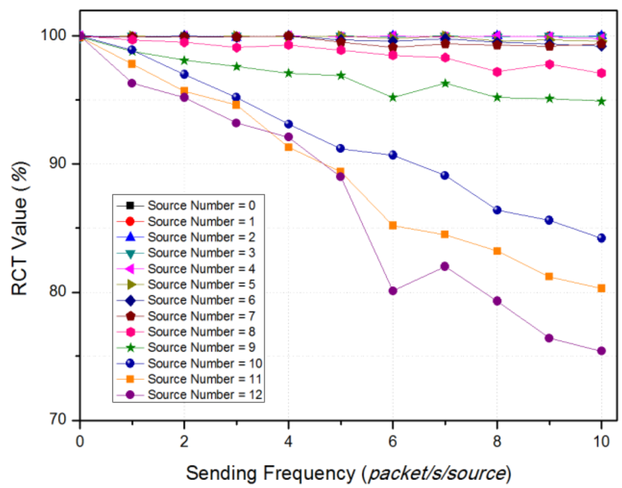
(c) Error rate of simulation when sending frequency is 2*packet/s/source*



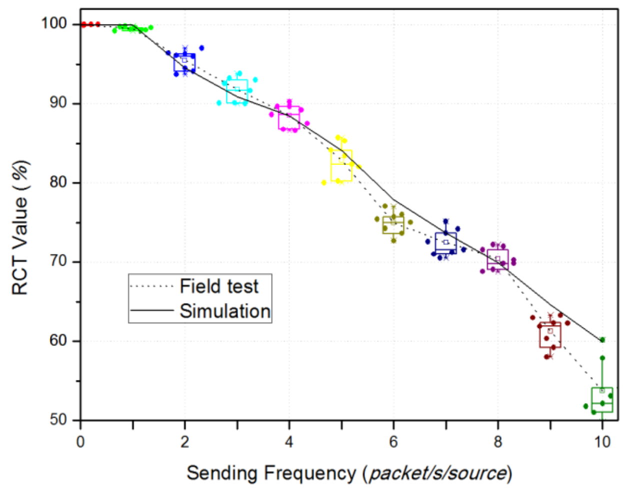
(d) Optimization process of source number when sending frequency is 2*packet/s/source*

Figure 7. Performance evaluation and optimization with variable source node number

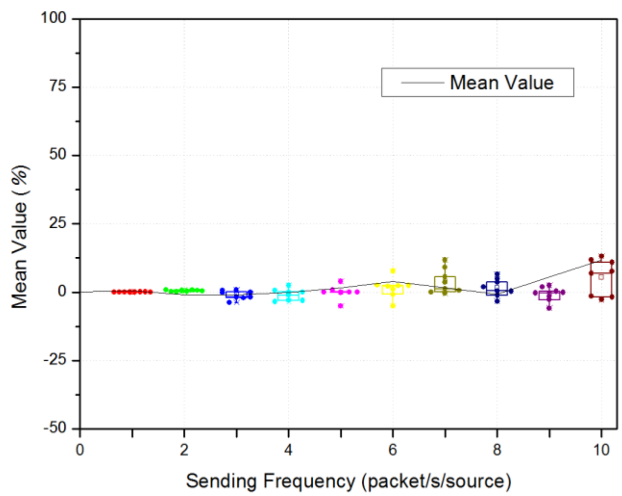
b. ii Discussion on variable of sending frequency



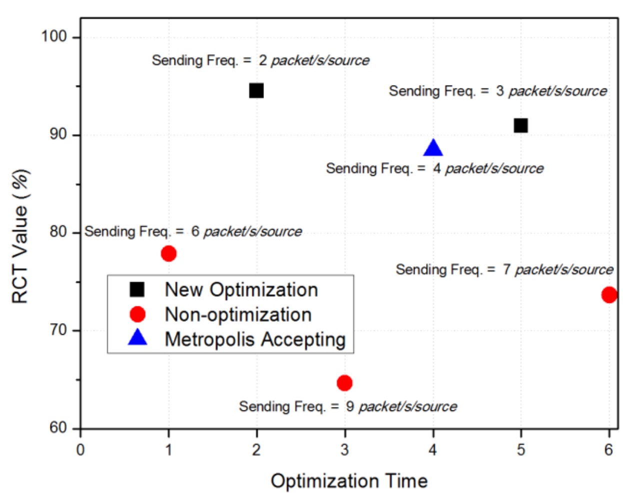
(a) *RCT* with variable source number (0~12)



(b) *RCT* comparison between field test and simulation when source number is 6



(c) Error rate of simulation when source number is 6

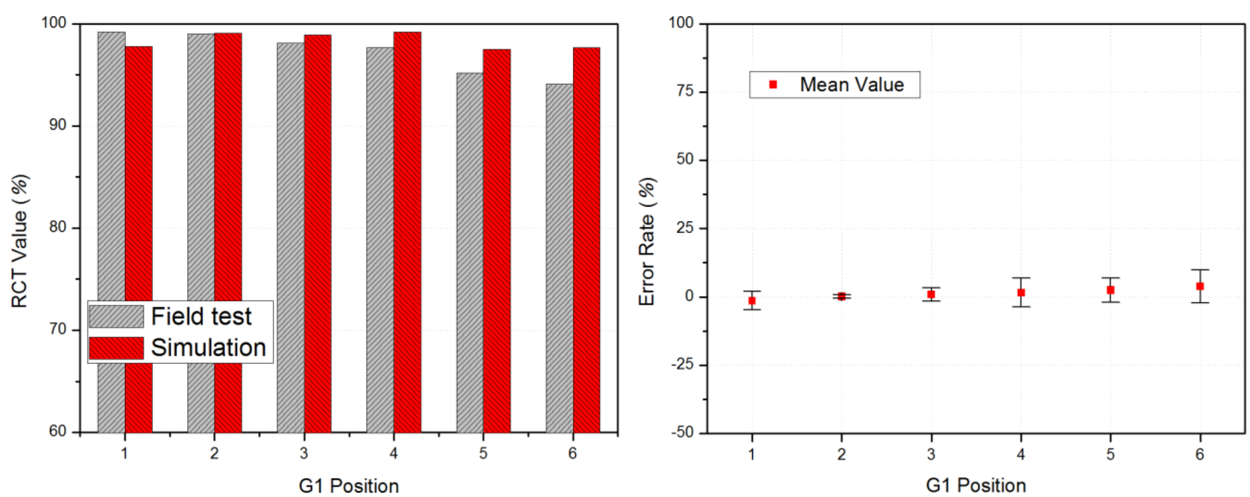


(d) Optimization process of sending frequency when source number is 6

Figure 8. *RCT* at variable user operation

Lowering network load is one of the best ways to enhance the system reliability. Except for reducing source number, changing operation frequency has the same impact on the performance enhancement. Therefore, we discuss the minimum time user should keep between two operations. Actually, not all e traffic at the APS layer can be successful sent to the MAC layer due to constraint of queue length in the hardware. This fact forms a kind of flow control at the APS layer to decrease the number of packets waiting to be sent. The packets at the APS layer could be sent to the MAC Layer successfully when the sending frequency is less than 1.03*packet/s/source*, Shown in Figure 8(a), *RCT* is decreasing with increasing sending frequency at the range of source number from 0 to 12. Figure 8(b) illustrates the comparison between field test and simulator in the case of 6 source nodes existing. The results of field test are changed on the same trend of that obtained from the proposed scheme. The error rate of simulation in this case is shown in figure 8(c), the maximum value of which is within 11%. Multiple source nodes promote the error rate because CC2430 is a kind of integrated wireless microcontroller. There are no detailed performance introductions of each component (such as RF frontend, power unit, and processer) so that the node model is not accurate. Figure 8(d) shows the optimization tracing of sending frequency when source number is kept as 6. The maximum number of optimization step is set as 6. The target *RCT* is set as 99*%*. The halt condition is that the number of outside loops is larger than that of optional locations. And the optimal value of sending frequency is 3*packet/s/source* which is get at the 5th step by S.A. algorithm.

b. iii Discussion on variable of node position



(a) *RCT* value of field test and simulation (b) Error rate of simulation

Figure 9. Performance evaluation with different G1 positions when source number is 8 and sending frequency is 5*packet/s/source*.

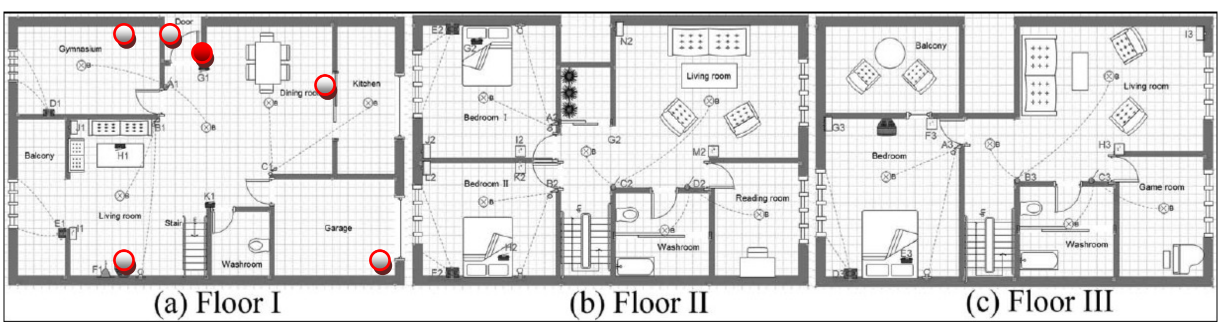
In this case, the end device G1 is selected as the optimal object which can be installed in six optional positions which are labeled as red circle in figure 10. Source number is set as 8 and sending frequency is set as 5*packet/s/source*.

Figure 9(a) shows the system performance in different positions. The error rate of simulation is shown in figure 9(b), the maximum value of which is within 3.2%.

Table 2: Optimization tracing of G1 location

Step	**3D Coordinates of G1**			**Optimization**	
	X (m)	***Y (m)***	***Z (m)***	***RCT (%)***	***Is opt.***
1	4.0	7.5	3.0	97.8	No
2	9.0	2.5	1.2	99.1	New Opt.
3	4.0	0.5	1.2	98.9	Metropolis Accepting
4	6.0	1.5	1.2	99.2	New Opt.
5	5.5	0.5	3.0	97.5	No
6	11.5	7.5	3.0	97.7	No

The optimization process is listed in Table 2. The maximum number of optimization step is set as 6. The target *RCT* is set as 99*%*. The halt condition is that the number of outside loops is larger than that of optional locations. Firstly, the initial position of G1 is randomly selected from the six optional ones. Figure 10 shows the optimal result of network deployment. The 3D coordinates of the optimal location of G1 is (6.0*m*, 1.5*m*, 1.2*m*) which is labeled as red solid circle in figure 10.



the optimal position via optimization process

the optional positions of G1

Figure 10. The optimal result of network deployment

VI. CONCLUSIONS

Computer aided simulation takes place of the traditional field test to provide a quick and effective way to evaluate the real scenario of WSC. The existing simulators are not suitable for the domain experts except for the professional software engineers. Thus, a model based application level middleware is present in this paper to assist the simulator in the system simulation. Friendly user interface makes all designers implement the simulation without constraint of professional knowledge. Huge model libraries guarantee the accuracy of simulation results and reduce the set-up time of a new scenario. Translation function provides the various simulation interfaces suitable for different simulators. Furthermore, this middleware has the function of automatic optimization to give the deployment suggestions to designers which is not provided by the existing simulators. The application of this platform highly reduces engineer costs and promotes design efficiency. Accurate and reliability performance evaluation and analysis can be acquired with the implementation of this platform.

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