Optimal Deployment Model of Key Pre-distribution Protocol for Heterogeneous Wireless Sensor Networks

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In recent years, heterogeneity has been widely adopted in Wireless Sensor Networks. Heterogeneity is an essential attribute of WSNs, which can help us obtain more practical network models, protocols with better performance and more accurate analysis.We study the effect of heterogeneities on performance of KPPs(Key Pre-distribution Protocols).Critical heterogeneities mentioned in this paper and their measurements are shown in Table 1, in which RCR means realistic communication radius and MCR represents the maximum communication radius.

Table 1. Critical Heterogeneities and Their Measurements

Symbol	Heterogeneity	Measurement
h_1	node heterogeneity	node type
h_2	communication radius heterogeneity	ratio of RCR to MCR
h_3	density heterogeneity	amount of neighbors

Researches have shown that rational use of heterogeneity could improve performance of KPPs and reach a global optimum. Let $O = \{o_1, \ldots, o_n\}$ and $A = \{a_1, \ldots, a_m\}$ be the object set and the attribute set of element e respectively. For the ith attribute $a_i \in A$ (whose corresponding heterogeneity is h_i), if there are k different attribute values $V_i = \{v_{i,1}, \ldots, v_{i,k}\}$ for all objects, the degree of HA(Heterogeneous Attribute) a_i is regarded as k, denoted by D_i. HA value distribution (HAVD) is seen as the number of nodes who share the same HA value. A KPP can be expressed as (t, m), in which t is the attribute set of key management tasks of KPP and m is the attribute set of key materials of KPP. Based on supernetworks theory [1], given a KPP, n heterogeneities existing in KPP-applied network and corresponding HA values, a optimal HA value distribution model (OVDM) can be displayed in Fig. 1. It indicates which HAVD can obtain the optimal performance of the chosen KPP (t, m).In Fig. 1, h_i denotes the ith heterogeneous attribute a_i affecting KPP. $h_1 \sim h_3$ are consistent with the data in the Table 1. Marked circles represent specific attribute value, task or material.

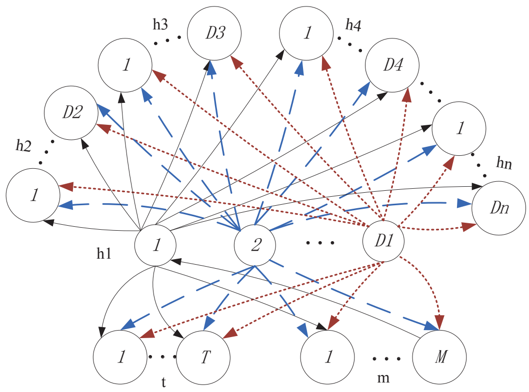

Fig. 1. OVDM of KPP $(t,\ m)$

In following research,the four metrics to measure KPPs are taken into account: cost, energy, connectivity and resilience. In order to solve multi-objective equilibrium optimization problem, we describe four corresponding objective functions of KPP optimization and convert these objective functions into equivalent variational inequalities. Global optimal performance, called equilibrium performance, is a tradeoff among the four performances mentioned. These performances are usually interdependent and interactive. For addressing the equilibrium constraint problem of KMP(Key Management Protocol), we need to find a feasible solution $(\boldsymbol{n}, \boldsymbol{m}, \boldsymbol{l}, \boldsymbol{\rho}, \boldsymbol{w}) \in R_+^{D_1+D_1\times M+D_1\times D_2+D_1\times D_3+D_1\times D_4}$ of the following inequality: $y_1 + y_2 + y_3 + y_4 \geq 0$

Our models can be easily extended to describe more complicated or special application-oriented network by adding more constraint conditions. Based on supernetworks and variational inequality theory, we proposed a optimal HA value distribution model (OHVM) and provided a method to find the optimal solution. Our model illustrated a simple way to depict the complex relationship between heterogeneities and protocols.

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References

1. WANG Z.P., WANG Z.T.: Supernetworks Theory and Applications. Science Press, New York (2008).