4

Reliable Aggregation Routing for Wireless Sensor Networks based on Game Theory

Qiming Huang, Xiao Liu and Chao Guo
University of Science and Technology Beijing
Communication Engineering Department
China

1. Introduction

Wireless integrated sensor networks, which include collecting, managing data and communication, are used more and more widely for their low cost and convenient deployment. Nowadays the research concerning each aspect of sensor networks is fairly active. Data Aggregation mechanism is one of the key problems in sensor networks. By considering the data transmission delay and overall network energy efficiency, this chapter develops a game-theoretic model of real-time reliable aggregation (RA-G) mechanism for wireless sensor networks.
Based on the study of related literatures, first of all in this chapter, the research status of WSN, the system architecture, the characteristics, and the critical technologies are summarized, current typical routing algorithms of WSN are classified and introduced one by one. Taking the implicit collaborative imperative for sensors to achieve overall network objectives (accomplish real-time collection tasks effectively) subject to individual resource consumption into account, this paper proposes a game-theoretic model of reliable data aggregation architecture in wireless sensor networks, defines a multi-tier data aggregation architecture in which semantic based aggregation and average computation aggregation is performed in sensor-level and node-level aggregation respectively. All nodes that detect the same target join the same logic group. Each selected group leader uses game-theoretic model which tradeoffs between energy dissipation and data transmission delay to determine the degree of aggregation. To meet the real-time constraints and balance the energy consumption between nodes, a decision-making model based on game theory which takes delay compensation into account is proposed in the data-relaying stage.
The simulation results show that the use of reliable data aggregation architecture can reduce the total transmission overhead of WSN, make the network more energy-efficient and prolong the lifetime of sensor network. On the other hand, the game-theoretic model used in group-level aggregation and data-relaying stage balance the tradeoffs between the energy dissipation and the timeliness of data transmission; therefore, also RA-G data aggregation mechanism is reliable.

2. Wireless sensor networks

Wireless sensor network is a data-centric wireless self-organizing network [1] consisting of a large number of integrated sensors, data processing unit, as well as short-distance wireless communication module. From the 21st century, sensor networks attracted academic, military and industry with great concern. The United States and Europe have launched a lot of research programs about wireless sensor networks and obtain the corresponding progress. The development of specific communication protocols and routing algorithm is the first issue of current field of wireless sensor networks need to be resolved.

2.1 Wireless sensor network architecture

The architecture of Wireless sensor network is shown in Figure 1.1 [2], wireless sensor network systems often include sensor nodes, Sink gateway nodes and the management nodes. A large number of sensor nodes deploy randomly inside of or near the monitoring area (sensor field), having ability of compositing networks through self-organization. Sensor nodes monitor the collected data to transmit along other sensor nodes by-hop. During the process of transmission, monitored data may be handled by multiple nodes, get to Sink gateway node after a multi-hop routing, and finally reach the management node through the Internet or satellite. The user configures and manages the wireless sensor network with the management node, publish monitoring missions and collect monitoring data.

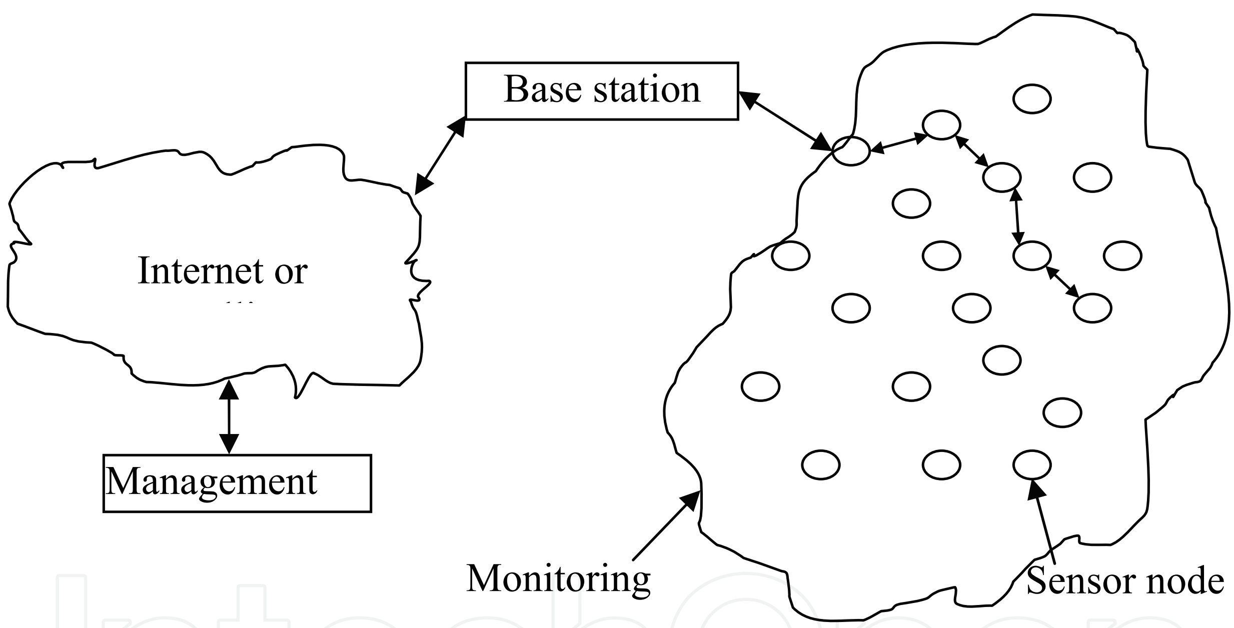


Fig. 1.1 Wireless Sensor Network Architecture

Sensor node is usually a tiny embedded system. It's processing power, storage capacity and communications capability is relatively weak, and the energy limited by carrying batteries. Sensor node consists of four parts [3] which are the sensor modules, processor modules, wireless communication module and power supply modules. Sensor module is responsible for the collection of information and the conversion of data in the area of monitoring; processor module responsible for controlling the operation of the sensor nodes, storage and processing their own collected data and the data sent by other nodes; wireless communication module is responsible for communicating wireless with other sensor nodes, exchanging controlled information, and sending and receiving collected data ; energy supply module provide the energy required to run for the sensor nodes, usually with a miniature battery.

Sensor nodes will be constricted by the limited supply of energy, communications capacity, computing and storage capacity, when achieving a variety of network protocols and applications. The features of sensor network are as follow:

1. Large-scale network [1, 2];
2. Self-organizing network [4];
3. Dynamic nature of networks;
4. Reliable network;
5. The application-specific networks;
6. The data-centric network [1, 2].

As a new research hot spot of information today, wireless sensor networks involve interdisciplinary field of study, and there are a lot of key technologies and researches to be found. The following list only some of the key technologies [1, 3, 5].

1. Network topology control. A good network topology generated automatically by topology control, is able to improve the routing protocol and the efficiency of MAC protocol and lay the foundation for many aspects such as data fusion, time synchronization and targeting, which will help to save the nodes and energy to extend the survival period of network. Therefore, the topology control is one of the core technology researches in wireless sensor networks.
2. Network protocol. Sensor network protocol is responsible for making all the independent nodes form a multi-hop data transmission network. The current study focused on network-layer protocols and data link layer protocol. Network layer routing protocols determine the transmission path of monitoring information; media access control of data link layer used to build the underlying infrastructure and control the communication process and work style for sensor nodes .
3. Network security. Ensuring the confidentiality of implementing the mandate, the reliability of data generation, the efficiency of data fusion and the security of data transmission is content which security issues in wireless sensor networks need to take full account of.
4. The time synchronization. Time synchronization is a key mechanism of sensor network systems needed to work together.
5. Location technology. Location information of sensor node is an integral part of the collected data. Determining the location of the incident or the node position of data collected is the most basic functions of sensor networks. Positioning mechanism must satisfy the self-organization, robustness, capacity-efficient, distributed computing requirements.
6. Data fusion. Sensor networks are constrained by energy. Reducing the amount of data can save energy effectively. Therefore in the process of collecting data from various sensor nodes, we can use computing and storage capacity of the local nodes to deal with the integration of data and to remove redundant information, thereby to achieve the purpose of saving energy.
7. Data management. From the view of data storage, sensor networks can be regarded as a distributed database. As a database method for data management in sensor networks, the logical view of data stored in the network can be separated from the realization of the network, making users of sensor networks need to only care about the logical structure of data query, no need to care about implementation details.

2.2 Comparative analysis of routing protocols of Wireless sensor network

After many years' efforts of national researchers, sensor network routing protocol algorithm has quite a number of results. According to the routing protocol algorithm, the network structure [10] can be divided into three categories as a flat routing, hierarchical routing and location-based routing; according to protocol operations rules, it can be divided into routing consultations, multi-path routing, QoS routing, query routing, etc. (Table 1.1 below). The following are introduced one by one by category.

Classification according to the Structural of network	Flat Routing	Directed Diffusion, SPIN, Rumor routing
	Hierarchical routing	LEACH, PEGASIS, EEN&APTEEN
	Location-based Routing	GAF, GEAR
Classification according to the protocol operation	Consultation route	SPIN, Directed Diffusion
	Multi-path routing	Directed Diffusion, SPIN, SPEED
	QoS Routing	SPEED
	Query Routing	Directed Diffusion, Rumor routing

Table 1.1 Classification of routing protocols of wireless sensor network

2.2.1 Protocol based on network structure

1. Flat routing protocols

In the flat multi-hop wireless sensor networks, flat routing protocols generally require each node to play the same role. Multi-sensor nodes implement acquisition of data synergistically. The studies for data-centric routing strategy have shown that energy can be saved through collaboration of multi-node operation and the elimination of redundant data, such as: SPIN [7-8] and Directed Diffusion [9-10]. Both protocols promote the other protocol design following a similar idea (i.e. data-centric routing method).

SPIN (Sensor Protocols for Information via Negotiation) [7-8]: W. Heinzelman and others made a class of adaptive SPIN routing protocol. The protocol assumes that all nodes in the network are potential Sink nodes, and each node can disseminate information to the other nodes in the network. It just needs to send the data which other nodes does not have. In addition, SPIN protocol classes also use the data negotiation strategies and resources adaptive algorithm. The node running SPIN protocol is assigned with each high-level data meta-data descriptor used to describe their data collected completely. Implementing the meta-data consultation before any data to be sent, to ensure that no redundant information transmit in the network. In addition, SPIN protocols have right to access the current energy level of each node, and adjust the running mold of protocol according to the residual energy level of node. Meta-data negotiation strategies of SPIN protocol solve the existing typical problems of the diffusion, thus improving energy efficiency and saving energy. However, the data broadcasting mechanism of SPIN protocol class can not guarantee that the data can transmit to the destination node.

Directed Diffusion [9-10]: C. Intanagonwiwat and others propose a new communication model of data acquisition for sensor networks, called directed diffusion. As a data-centric (DC data-centric) and application-aware communication model, directed diffusion protocol requires all of the data generated by sensor nodes named with attribute value pairs. The main idea of the model DC is a purposes to eliminate redundancy and minimize the amount of data transfer through data fusion of different sources nodes and re-routing, thus saving energy and extending the life of the network system. DC routing policy can find the path from multiple sources nodes to a single destination node and take the operation of redundant data fusion in the net. Comparing SPIN protocol, the capability of directed diffusion protocol to adapt to the environment in mobile applications is weak. In addition, the DC communication model may not apply to the application which requires a sustained data transmission to Sink node, and the query and data-matching work may require additional overhead.

2. Hierarchical routing protocols

Hierarchical or clustering routing strategy, first proposed in the wired network, is a better scalability and communication efficient routing. Hierarchical routing reduce the amount of data transmitting to Sink node through the implementation of data fusion, reduce energy consumption of each node within the cluster, and it is an effective solution to improve energy efficiency. Hierarchical routing mainly constituted by two levels: one level is used to create clusters and select the cluster head node, another level is used to integrate and process the collected data and routing data.

LEACH (Low Energy Adaptive Clustering Hierarchy) [11] [12-13]: W. Heinzelman and others propose a hierarchical clustering routing algorithm for sensor networks. It is a clustering routing protocol using distributed cluster formation technique. LEACH select a number of sensor nodes randomly acting as cluster head nodes (CHs, Cluster-Heads), so that all nodes take turns to act as cluster head nodes to bear the cost of energy evenly. In the LEACH protocol, the cluster head node integrate the data collected by all non-cluster head node (non-CHS, non-Cluster-Heads) which belong to it, and then sent the integrated data packets to the Sink node to reduce transmission volume of data. Table 1.2 compares SPIN, LEACH and Directed Diffusion routing technology according to the different parameters. It can be seen from the table that directed diffusion protocol is an energy-efficient routing of compromise due to the use of network processing and optimization path method.

	SPIN protocol	LEACH protocol	Directed Diffusion protocol
Optimal path	No	No	Yes
Internet Life	Well	Well	Well
Resource-aware	Yes	Yes	Yes
The use of meta-data	Yes	No	Yes

Table 1.2 SPIN, LEACH and Directed Diffusion protocol comparisons

TEEN (Threshold-sensitive Energy Efficient sensor Network Protocol) [14] and APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network protocol) [15]: these two kinds of hierarchical routing protocols are proposed for time-critical data acquisition application. In the TEEN protocol, sensor nodes collect information constantly, but the process of data transfer is less. A cluster head node send a hard threshold (collection attributes), and a soft-threshold (can lead a change of sensed attribute value range for the node open the transmitter to transmit data) to its members. Only when the sensed attribute value in the context is in the range of interest, it will be allowed to transfer data.

The simulation results of TEEN and the APTEEN show that these two types of protocol are better than LEACH protocol in operational performance. It is proved by Experiment, according to energy consumption and network lifetime, the performance of APTEEN is between LEACH and TEEN. TEEN provide the best performance because it reduces the number of transmissions. The major shortcomings of these two protocols are the increase of the cost and complexity which is related to the formation of a multi-level class, the realization of the methods based on threshold functions and how to deal with the increase's cost of attribute based on named query methods.

3. GIS-based routing protocol

In this type of routing protocol, sensor nodes depend on the location information to address. The distance between neighbor nodes can be estimated by the arrived signal strength. The relative coordinates of neighbor nodes are get through the exchange of information between the nodes [16-17, 18]. In other words, if the node equipped with small low-power GPS receiver [19], nodes can get location information through communications with satellite directly using GPS. To conserve energy, without uncertain situation, some strategy based location information requires the nodes go to sleep. Make as many nodes as possible in sleep, so that the network can save more energy. The problem of designing table of the sleep cycle scheduling with a fixed way for each node are discussed in [19-20].

2.2.2 Protocol-based protocol operation

1. Negotiation-based routing protocol

These protocols using advanced data descriptors reduce the amount of data transmission through consultation to eliminate redundant data. Communication decision-making is made also based on the resources available to them. SPIN protocol suite [11-12] are examples of routing protocols based on negotiated. Motives of consultation are: to avoid the defects of diffusion, which will produce the problems of information explosion and overlap, so the node will receive multiple copies of the same data. This operation will consume more energy, bandwidth, and to spend more processing time due to send the same data to different nodes. The important ideal of negotiation-based routing protocol is to eliminate duplicate information, avoid redundant information sending to the next node or Sink node and do a series of operation in consultations before sending the actual data.

2. Multi-path routing protocols

In order to improve network performance, such protocols will use multi-path data routing rather than a single path. The fault-tolerant of protocol according to exist possibility of other alternative path when the basic path between source node and destination node fail. Increase of the fault tolerance get from maintaining the multi-path between the source node and destination nodes, with the ever-increasing cost of energy consumption and traffic generated. The paths of choice maintain its vitality through sending the message periodically, so increasing network reliability and fault tolerance is obtained through maintaining a number of alternative paths available with increasing cost.

3. QoS-based routing protocol

Once considering the performance QoS when address data, network has to strike a balance between power and data quality. Especially when the node to send data to Sink node, the network has to meet some QoS criteria, such as: delay, data accuracy, bandwidth utilization rate and so on.

4. Routing protocol based on query

Such routing protocols are characterized by: the destination node transmit a query through the Internet for collecting data needed to complete tasks, then after a node that owns the data match the query, we send the data back to the node starting the query, which is the destination node. Usually these queries are described by natural language or high-level query language. All nodes have a table consisted of query mandates they received. After receiving a query, they send the data matching with the queries. Directed diffusion protocol [7] is an example of this kind of routing. In the communication model of directional diffusion, Sink node sends interested information to all nodes. Once the interest spread through the network, the gradient is established which is from the source node to Sink nodes. When the source node has the data of the interest, the source node send data along the interest gradient path. To reduce energy consumption, it implements the routing after data fusion.

We provide an overview of a variety of routing algorithms above according to different classification, compare similar routing algorithm and point out their advantage and disadvantage.

3. An overview of game theory

Strictly speaking, the game theory is not a branch of economics. It is a methodology, whose scope of application is not limited to economics. Political science, military, diplomatic, international relations, public choice, criminology are related to game theory. Many scholars have already introduced game theory into the field of communication, including flow control, routing algorithms, power control. Game theory, also translated as game theory [21], is to study the decision when the behavior of decision-making body makes a direct interaction, as well as the balance of this decision-making.

Presentation of a complete game problem requires at least three basic elements: player, strategy set, and payoff function.

1. Player

Player is the immediate parties involved in game. He is the main maker of decision-making and strategy of game. In a different game, the player means different which can be individual, group or collective, but these organizations or groups must be for a common goal and interests to participate in game. Player should know clearly their own goals and interests and always take the best strategy to achieve their maximum effectiveness and interests in the game.

2. Strategy set

In a game, a practical, feasible and complete action which is available for participants to chooses to be called a strategy. Strategy set is all the possible set of strategies taken by player. It is the tools and instruments for player to play, and each set should be set at least two different strategies. Strategies from each strategy set in game forming a game situation.

3. Payoff function

When strategy set adopted by all players is determined, they have their own "payoff function" or "profit function". Payoff function express the level of the income or utility can be get from the game by player, which is the function of strategy for all players. Different strategies may lead to different benefits, which is the thing each player really cares about.

In game theory, one of the important bases for each player to make a rational decision-making is the amount of his possible profits, which is an insider need to calculate carefully the profit function. The structure and values of profit function will undoubtedly affect the player's behavior, thus also affect the final outcome of the game. As a result, the determination of profit function is a very important matter in game theory study.

Considering different point of view for game, a player can have all kinds of profit function which is not unique.

3.1 Nash equilibrium

Game theory is a mathematical tool used to study the decision when the behavior of decision-making body makes a direct interaction, as well as the balance of this decision-making. In other words, it is decision-making problems and balance issues when a choice involved in a subject is impacted by the choices of other subjects and return to influence the choice of other subjects. The most basic components of game theory is the game concept, using the formula is expressed as $G = \langle N, A, \{u_i\} \rangle$, where G is a specific game, $N = \{1, 2, \ldots, n\}$ is a limited set of participants (decision makers), A_i is a collection of optional behavior of the participant i, $A = A_1 \times A_2 \times \ldots \times A_n$ is behavior space, $\{u_i\} = \{u_1, u_2, \ldots u_n\}$ is the maximum effectiveness (objective) of function set which participants hope to. Each objective function of participant u_i is a function of the special action a_i selected by a participant i, but also the functions of the action a_{-i} chosen by all the other players in this game. That is to say the individual objective function depends not only on its own choice, but also on other participants' choices. Game may include some additional components, such as the information and communication mechanisms [21] which each participant can make use of.

For the game, the basic concept of steady state is the Nash equilibrium. In the Nash equilibrium, there is no node which can improve its objective function value through unilaterally deviating from the value of the state. For example: a^* is the steady state, only if:

$$u_i(a_i^*, a_{-i}^*) \geq u_i(a_i, a_{-i}^*) \forall a_i \in A_i, \forall i \in N . \qquad (1.1)$$

These steady states can predict the output of distribution algorithms. Strategy a_i^* is a "best" strategy chosen by participant i in the face of opponents; this is true for all participants. Game result is "stable", which means that no participant has a incentive to deviate from this choice unilaterally; in a sense, Nash equilibrium is a "no regrets" solution of game.

Another expression for Nash equilibrium is sometimes very useful. For any $a_{-i} \in A_{-i}$, we define the best set of participants:

$$B_i(a_{-i}) = \{a_i \in A_i : u_i(a_i, a_{-i}) \geq u_i(a_i', a_{-i})\}, \text{ for all } a_i' \in A_i \qquad (1.2)$$

In general, B_i is called the "best response function" of the participants, so we can define Nash equilibrium to a strategy vector $(a_1^*, \ldots a_n^*)$, where $a_i^* \in B_i(a_{-i}^*), \forall i \in N$.

A very important point is: in many cases, the concept of the solution of a game exists logically. In fact, the concept of Nash equilibrium is used widely because it exists in many games.

3.2 Incentive theory

Motivation theory [22-23] is one of the most important applications for the game theory in economics, which have a wide range of applications in all fields. It reveals the asymmetric information as an important role played in economics. The main analytical framework for incentive theory is made in the principal-agent relationship model. In this relationship, there is a principal and one or more agents, as agents have the expertise or unique information which a principal does not have, or simply because the client not has the time and energy to deal with certain things, the principal delegate an agent to deal with certain matters which originally belongs to his power or responsibility.

4. The model of data fusion based on game theory

In this section, the idea of game theory will be introduced to the wireless sensor networks to model RA-G (Reliable Aggregation based on Game theory) for delay and the energy efficiency of nodes integration of the data fusion mechanism. By the introduction of wireless sensor networks, we can see that the network node has features of severe restrictions on bandwidth resources, energy, storage capacity and computing. In the integration phase, each intermediate node want integrate sufficient data packets before sending data to minimize their consumption of energy required to send data. The more integration nodes collect data packets, the more accurate for the description of monitored goals, that is the accuracy of the information; but on the other hand, collecting more data packets need to wait for the longer integration time, which will lead that the final information delay received by network users would greatly increase. This situation is intolerable for real-time target tracking system. This shows that the above-mentioned factors in the network are contradictory. For the node, it want to save as much as possible the energy of their own bandwidth resources, and for the network, the delay is a key issue, that is to say the nodes and the interests of network exist contradictions; when the fusion node transmit fused data packets to the sink node, there is another issue to be considered. As each node in each period play different role and with different status, in data transmission phase, nodes have to weigh their own needs to send data and to forward data services for other nodes. On the one hand, when the node need to send data, other nodes can provide forwarding services; the other hand, each node try to forward the data as less as possible for the other nodes in order to reduce power consumption. But if all nodes are not willing to forward data for other nodes, then the connectivity of network will decline sharply and reliable real-time transmission of data packets can not be guaranteed, and ultimately affect the overall performance of the network seriously – which is also a contradiction between nodes and the interest of network.

Game theory is a good mathematical tool in dealing with such a conflict of interest. The following section will build a determination model of intermediate nodes integration based on game theory for the real-time target / event monitoring system, and make some preliminary attempts on node incentive mechanism.

4.1 Real-time target / event monitoring system

Real-time target / event monitoring [24] system consists of hundreds of tiny sensor nodes, which can monitor and track goals efficiently and real-timely within the monitoring region, and distinguish the targets. The result will be reported to end-users via satellite or cable network by sink node. This section used the integration of hierarchical models [25] to achieve efficient use of energy. If the particle size of integration is too small, a lot of useful information of the collected raw data may be premature loss; however, if the particle size of integration is too large, it will make wireless sensor networks consume excessive energy for transmitting data and maybe cause serious network congestion and loss of information. Therefore, in this section, real-time target / event monitoring system use a mechanism of hierarchical integration to solve the above problems, as shown in Figure 1.2 for the schematic of hierarchical integration.

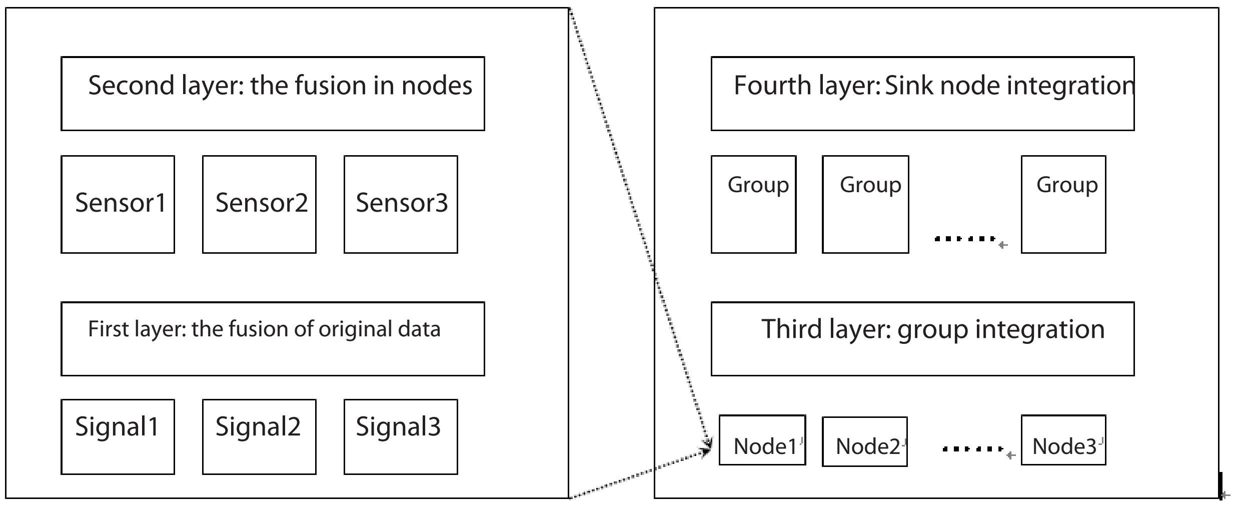


Fig. 1.2 the schematic of hierarchical integration

The first layer is about the fusion of original data. Data collected by sensor are the original input of the entire network. The integration in this layer provides the basis processing for the information of the tracked targets / monitoring of events in the network. Data fusion of this level must meet the following requirements: 1) meet the real-time constraints; 2) be able to handle a large number of input data. In order to enhance energy-saving effect of the integration operation, this layer operation of data fusion is semantics-based integration. By extracting the semantic of raw data collected from sensors to achieve higher efficiency integration.

The second layer is fusion in node level. Each sensor node integrates several different types of sensors. After collecting self-confidence vector of different sensors, nodes do the further integration. It will calculate the average of all nodes' confidence vector, and then forming a single node-level confidence vectors. Semantics of sensor data should be extracted and fuse at the node level, classification module of perception algorithm and the node level need to cache and deal with selected data. Here the processing time require in a reasonable range.

The third layer is group integration. When the node level fusion gets monitored results, we began to estimate related information of the current target, and should uniquely determine the monitored objectives in logic. During the preliminary estimate, we should let the collected information about the target location of each node use their confidence vector as the weight to the average all the monitoring value. This involve an issue is when and where the estimated calculation of such a collection should be done. Representation about the target is a classic problem. There are already a number of centralized or distributed algorithms of temporal and spatial correlation to achieve. In this system, there are two related mechanisms used in this layer.

1. The fusion method based on logic group

In the target / event monitoring system, there are two main tasks which are to collect relevant information of objectives and to represent goals. A simple solution is sending the monitoring results, the location and other information of all the nodes to a central base station, to estimate the current location and other information based on the location information [26-27] of all nodes sending the information and other related information collected, and in the process, to the use of space-time related algorithm to give and maintain the coherence for the sole objective. But the efficiency of this centralized mechanism is low both for energy consumption and delay. Sending the large amount of data report to the base station will cause excessive energy consumption, and if the target is far away from the base station will greatly increase the delay. In order to avoid the shortcomings of the above mechanism, using a distributed mechanism is a solution. Processing the data near the monitored target / event, and then sent fused information to the base station for further operations.

2. Balance of energy and delay based on Game Theory

In the group fusion layer, managing the node need to wait for some time to gather the data report of members in group, and integrate these reports, then forward to the Sink nodes through other nodes. In this process, there is a variable parameter need to be considered, degree of aggregation DOA, which is a direct expression to show whether the management node has received a sufficient number of reports of group members. That is to say the management node doesn't operate the fusion before receiving to a member of sufficient DOA data reports in group. In the management nodes, the problem of balance description need to be considered are as follows: For the management node, the larger DOA values means the more members' data report can be collected to fuse, and then sent data packets of once fusion. It compared with the situation of smaller DOA, obviously management node can save more energy consumption on sending data and is conducive to reducing the load nodes of transmission; while for the network users, the goals of real-time monitoring are the ultimate goals of the network. If the DOA value is so large that the producing delays beyond the limits of real-time systems, it will inevitably harm the interests of Internet users, resulting in unavailable purpose of real-time monitoring for target. In above process, the interests between the nodes and network create a conflict, which is needed to use some mechanism to guide the behavior of nodes in order to balance the interests of both.

From the above description we can see this game model's participants are nodes and networks, which should be a two-game model with incomplete information. Supposing energy saving through the data fusion by management node is E_p, while the wait time of fusion which is the increased delay for participants in network is T_{aggr}. Now we come to quantitative analysis the impact of DOA for E_s and T_{aggr}.

1. Energy savings in fusion

In real system, due to the impact of various factors, such as sensing range, target movement model and the node density, doing the analysis is difficult. Here we make some simplifying assumptions to do approximate analysis. Suppose sensing range of sensor nodes is a circular area with a radius *R*. The target moves forward with uniform speed along the straight line, and nodes in an unlimited sensor network are uniformly distributed.

Figure 1.3 shows the schematic diagram of target and monitored region. The red star represents the position of target. The sensor node in the circular can sense this target then forming a logical group. The sensor nodes with the dark mark are the managed nodes of logical group. Supposing the number of members nodes in group are n_g. If the value of DOA is 1, that is, don't do the operation of fusion in the management node. So for the management node, the energy consumption of sending group members required for data reporting is showed as follows:

$$E_{T-woaggr} = n_g \cdot (lE_{elec} + l\varepsilon d^r) \tag{1.3}$$

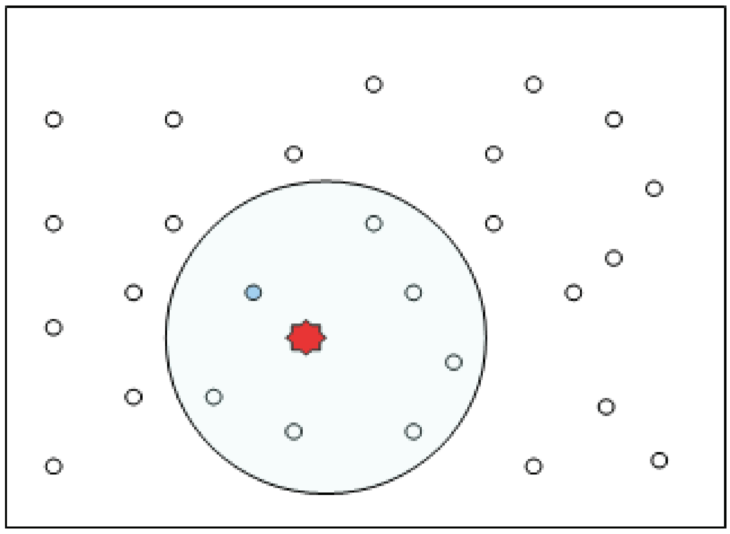


Fig. 1.3 Monitored region

Where, l is length of a data packet. E_{elec} is the energy consumption per bit data for sending or receiving circuit. The constant ε is related with the transmission channel model used. ε_{fs} is the free-space transmission, the corresponding r is 2. ε_{amp} is the multi-path fading transmission, the corresponding r is 4. When the distance d between the transmitter and receiver is less than the threshold value d_0, we use free-space transmission model. On the contrary if d is more than or d_0, we use multi-path fading model. When the management nodes do fusion of data, the value of DOA is a positive integer more than 1 and not more than n_g. At this point, the DOA data reporting of the members' nodes in group will be received and integrated by management nodes. Thus the energy consumption of sending the members' data reporting in group by nodes is:

$$E_{T-aggr} = (n_g - DOA + 1) \cdot (lE_{elec} + l\varepsilon d^r) \tag{1.4}$$

We can draw the conclusion from the above two equations, when $2 \le DOA \le n_g$, the percentage of energy savings by managed node is:

$$E_P = 1 - \frac{E_{T-aggr}}{E_{T-woaggr}} = 1 - \frac{n_g - DOA + 1}{n_g} \tag{1.5}$$

The above equation reveals the relationship between the saved energy obtained by data fusion in management nodes and DOA. In the game model discussed in this chapter, we define E_P as the benefits obtained by management nodes through the integration.

Definition 1.1 The proceeds of management nodes in Game model of group-level fusion are as follows:

$$X_I = E_P = 1 - \frac{n_g - DOA + 1}{n_g} = \frac{DOA - 1}{n_g} \tag{1.6}$$

2. The impact of convergence on the network delay

After management node generates its own data or receives the data reports of group member, it doesn't transmit them immediately but wait for a while to obtain sufficient data reporting, then do the fusion of data and transmit the fused data packet. The management nodes in this article can integrate a number of its data-reporting received through data fusing and processing into a new isometric data reporting, and the computing time of integration is much smaller than the data transmission time. Therefore we ignore this data-processing delay.

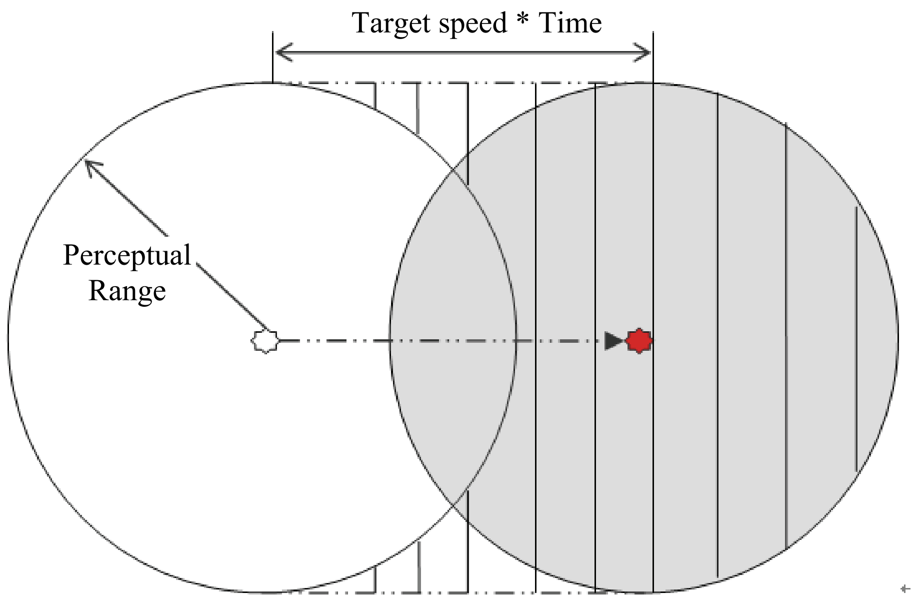


Fig. 1.4 Schematic diagram of the moving target trajectory

In Figure 1.4, goals move with speed *TS* for some time *T*, the target's perception range is *SR*. White and gray circular area represents the perception of the region of the target mobile before and after moving respectively. Nodes in the vertical shaded area are the existent new sensor nodes perceived after targets begin to move. The management node in the shadow need collect DOA data packet of members' nodes to start data fusion. The delay for that is as follows:

$$T_{aggr} = \frac{DOA}{2 \cdot SR \cdot TS \cdot D} \tag{1.7}$$

If the density *D* and sensing range *SR* of nodes in the network are determined, we can see that here the delay is related with DOA and moving speed *TS* of target. In the game model of this chapter, the longer time the integration of the management nodes are waiting for, more negative for real-time targets of the network. So we define the delay brought by integration as the penalty factor of the network for the management node, while getting the energy gains, management node must pay the price. Internet users can guide the behavior of management nodes through the definition of punish to make it operate in reasonable range.

Definition 1.2 The cost of the delay of the management node in group-level integration is showed as follows,

$$C_I = DOA^{f(TS)} \tag{1.8}$$

Where *f*(*TS*) is a function of target move speed, and the output is a positive number between 0 and 1. In the real-time monitoring system, the faster movement of the target the shorter the time is needed for information monitored to send to the Sink node. Here $f(TS)$ is the function of the urgency for sending the data reporting to the node, and it increase with the accretion of the target moving speed. So the expression of $f(TS)$ is showed as follows,

$$f(TS) = \text{Monitored target speed} \; / \; \text{The greatest possible speed of target} \quad \text{(Eq.1.9)}$$

From equation 1.9 we can see that the output increase with the target moving speed increases, that is to say the targeted information monitored has the higher degree of urgency.

3. The definition of game model

Definition 1.3 From the above analysis, we can define the utility function of management nodes in a balanced game for the energy and delay as follows,

$$U_I = X_I - C_I = \frac{DOA - 1}{n_g} - DOA^{f(TS)} \tag{1.10}$$

At this point, GA-G(Group Aggregation based on Game theory) can be described as follows.

1. Participants

In the game the two sides of the conflict of interest are manage nodes and network users.

2. Strategy

Management nodes evaluate the urgency of this monitoring information through the related information of goal monitored by the nodes of the members in group and themselves, which is the output value of the function $f(TS)$. It increases with the moving speed of target increases, which show the higher the degree of urgency for the information; in the game of this article, the management node as to networks can take the value of DOA which is more conducive to its own energy savings to carry out the operations of integration; while for networks, through avoiding the excessive delay, using penalty for delay to constraint the behavior of management node, punishment is harder as the intensity of target information increased, so that it is better for a high degree emergency information can be transmitted to the Sink node with the smaller delay.

3. The expression of utility function as follows:

$$\max U_I = \max\left(\frac{DOA - 1}{n_g} - DOA^{f(TS)}\right) \tag{1.11}$$

Where the constraint condition is the value of DOA can not exceed the number of members' nodes in group n_g and no less than 2. Because in the real network, if the set for DOA over n_g, the management node will never do the operations of integration; and the values of nodes should be the value when the utility of nodes to take the largest value of DOA.

Therefore, the optimal value of DOA as follows:

$$DOA_{opt} = \underset{2 \le DOA \le n_g}{\arg\max}\left\{\frac{DOA - 1}{n_g} - DOA^{f(TS)}\right\} \tag{1.12}$$

4. Qualitative Analysis of Game Model

In above model, the constraint condition is $2 \le DOA \le n_g$. Considering the case when DOA take 1, there is equivalent to introduce no group-level fusion mechanism, therefore, no data integration operation of the management node is involved in. That is, all nodes perceiving objectives transmit its data to Sink node through multi-hops after collecting the required data. There are not considerations for the balance of energy consumption and delay, therefore there is no such thing as a balanced solution; when $DOA \geq 2$, group-level integration mechanisms began to play its role and need to balance the energy consumption and delay in the management nodes. In this game model, the benefit of management node is $(DOA - 1)/n_g$. During a target / event monitoring process, sensor network nodes which perceiving the same target / event form a logical group. In the initial stage of group, the nodes can know the information of other neighbor nodes in group through interaction, and in a short period of time, the node monitoring of the goals / event is determined, that is to say n_g is certain. In this context, we can see the benefits of management nodes increase with the value of DOA increases. Meaning mapping to the network is that the more data reporting of members' node is collected, the management node can save more energy in transmitting data. Here it also implies a network parameter, the quality of information. If management node collects more data reporting of member' node in group, more accurate description of the targets / event then for monitoring is shown. When the members of the group increase, that is to say n_g increases, the management node consequentially increase the corresponding value of DOA, in order to obtain substantial benefits. It is good for both the energy savings and the accuracy of the information, and useful for the management node; in order to avoid excessive selfish of management node and setting too large values of DOA to get own interest which will lead to the large transmission delay of information, the network need to set the penalty factor to constrain the behavior of the management node. It is expressed as the second one $DOA^{f(TS)}$ in this model. While getting the benefit through the operations of integration, management node has to pay the appropriate price. The greater value of DOA, the delay will be greater, which means that while getting more revenue, management node also suffer the more punishment from the network. And in the real-time monitoring system, the moving speed of target/event is also the factors that must be considered. If the moving speed of goal is fast, then the propagation delay of information will be small. In the model, the index $f(TS)$ of DOA is an adjustment factor for the corresponding speed. $f(TS)$ will increase with the moving speed of the monitored target increases. When monitoring a fast moving target, the costs paid by the management node are higher than monitoring a low moving target. At this time, if the management node takes the greater the value of DOA, the punishment received grow faster, which is negative for the management node on the contrary. At this time, for the management node and network, the balance effectiveness is $\max((DOA\text{-}1)/n_g - DOA^{f(TS)})$. From the above discussion, we can see that the game model of management node can adjust the value of DOA according to the actual situation in the network to reach the balance between the interests of two sides, thereby improving overall effectiveness.

4.2 Game model of data packet forwarding

After fusing the collected data reporting of the members in group, management nodes need to forward packets through other nodes to the Sink node. In traditional routing in wireless sensor, we assume that all nodes are selfless, that is, when each sensor node receives a request of forwarding, it will accept the request and forward the received data packets. In order to extend the life cycle of sensor networks, this chapter describes a approach which use the self-serving nature of the nodes to balance the energy consumption of the network, making the energy consumption of network nodes in a balance state and the result is that the whole network will not split quickly.

We use game theory to solve the following conflicts of interest. The nodes in wireless sensor network are rational, which means there is certain selfishness and their actions are driven by self-interest. On the one hand, each node hopes that other nodes can't provide services of forwarding when it send data; the other hand, each node wants as little as possible on forwarding data for other nodes to reduce energy consumption. However, if all nodes are not willing to forward data for other nodes, then the connectivity of network will be a sharp decline, and even become non-connection; Moreover, the application background of this section is a real-time monitoring, so how to balance the energy while does not to cause too large delay is also a problem needed to be solved.

The game model of final stage for forwarding data described as follows:

1. Game participants

Game in the stage of data forwarding is defined as an extended two-person incomplete information game. The game participants are nodes and networks. For each node in the network, supposing the total number of transmitted data packets sent by this node to other nodes is $R_i(t)$, the number of successfully transmitted data packets sent by the network nodes for this node is $T_i(t)$; of these, $T_i(t)$ present that the number of successfully transmitted data packets of node i forwarded by other nodes in the network until the time t; $R_i(t)$ present that the number of transmitted data packets of node i forwarded by other nodes in the network until the time t. $f(TS)\cdot\lambda$ is the available delay compensation for agreeing to forward data packets.

2. The strategy set

This phase of the game is the extend game. For the extended game, the game participants can not predetermine a complete program of action. Participants' operations of every step are chosen based on the behavior of other participants before. In the game of this chapter, for this participant in network, the action of the node which can be taken includes accepting the forwarding request of the network to forward the data packets. At this time, the node can get the delay compensation from network. In a certain extent, such a mechanism encourage the nodes accept a forwarding request to reduce the forwarding delay of data packets; or deny the forwarding request of the network, which need to pay a certain price at the same time. Because the node refuse to forward the request means that a certain amount of delay is brought to the network. The action of the relative node can be taken include accepting the forwarding request of the node to forward the data packets, or refusing the forwarding request of node. Whether the node or network, decision of whether to accept the other's forwarding request is based on whether the other side forward a sufficient number of data packets for themselves and the corresponding delay compensation.

3. Utility function

From the perspective of each node, when the network forward packets successfully for this node, it means that the node obtain interest from the network. When the node accepts the forwarding request of the network to forward data packets for the network, it means that the node pay costs for the network. As the average number of hops α crossed by the exchange of data between the nodes and Sink nodes are no less than l, the benefits received after every successfully sending a own data packet is α times than the loss for forwarding a data packet for the network. This encourage the nodes in network involving in data forwarding; in addition, though the node's utility function is less than zero, if the node agree to forward the data packet, then it will get awards from the network, which is delay compensation, to encourage the node forwarding data; however, if the node refuse to forward data packets, then it will don't get the value of delay compensation, as a punishment to nodes from network.

As a result, the mathematical expression of utility function in the model of DR-G (Data Relaying base on Game Theory) is as follows:

$$U'(T_i(t),R_i(t)) = \alpha \times T_i(t) - R_i(t) + f(TS)\cdot\lambda$$

From above equation, we can introduce a decision function of node forwarding as follow, which is used to determine whether forward data for the other nodes.

$$\Delta'\left(T_i(t),R_i(t)\right) = \begin{cases} 1, & \alpha \times T_i(t) - R_i(t) + f(TS)\cdot\lambda \geq 0 \\ 0, & \alpha \times T_i(t) - R_i(t) + f(TS)\cdot\lambda < 0 \end{cases}$$

Where, $\alpha$is the average number of hops crossed by transmitting a data packet to the sink node, $f(TS)\cdot\lambda$ is the available delay compensation for agreeing to forward data packets. When the value of $\Delta(T_i(t),R_i(t))$ is 1, the intermediate node i agrees to forward; when the value of $\Delta(T_i(t),R_i(t))$ is 0, the node i refuses to forward.

4.3 Nash equilibrium of Game Theory model

The game model of forwarding a wireless sensor network's data packet was defined in the previous section, and in this section we will discuss that model. The main analysis of the content is that during the network operation the game model which was proposed above plays the role of the energy consumption of a balanced between the nodes with the passage of time. In which the delay compensation is different with the different target. Each goal is randomly independent of each other. The previous goals will not influence of the characteristics of a next target. Therefore, in the discussion does not involve the delay compensation of the model.

Wireless sensor networks which using the sensor nodes for forwarding decision function, for the network nodes i, there are

$$\limsup_{t\to\infty} \delta_i(t) \leq \frac{1}{\alpha+1} \tag{1.13}$$

In which, $\delta_i(t)$ means that until the time t, the proportion of the number of packets which send data packets of its' own successfully the proportion among total which the node i had sent, that

$$\delta_i(t) = \frac{T_i(t)}{T_i(t)+R_i(t)} \tag{1.14}$$

When the node's utility function value is zero, that: $\alpha \times T_i(t) - R_i(t) = 0$ The corresponding network participants' utility function value is also zero because it is a zero-sum game. At this point, if the network node received the packet request, it will refuse to forward. When $t \to \infty$, only after the node i had been forwarded at least αdata packets for the network, the network will re-forward the data for the node i. Before this there is $\alpha \times T_i(t) \leq R_i(t)$, added $T_i(t)$ both sides of this inequality, that

$$\alpha \times T_i(t) + T_i(t) \leq R_i(t) + T_i(t) \tag{1.15}$$

Into

$$\frac{T_i(t)}{T_i(t)+R_i(t)} \le \frac{1}{\alpha+1}, \quad \text{that is } \delta_i(t) \le \frac{1}{\alpha+1}$$

When $\alpha \times T_i(t) \ge R_i(t)$, the node i will forward data for other nodes, there are $(T_i(t) + 1) \times \alpha \ge R_i(t)$. From this inequality can be derived $\alpha \cdot T_i(t) + \alpha + T_i(t) \ge R_i(t) + T_i(t)$, both sides are divided $T_i(t) + R_i(t)$, that

$$\frac{\alpha \cdot T_i(t)}{T_i(t)+R_i(t)} + \frac{\alpha}{T_i(t)+R_i(t)} + \frac{T_i(t)}{T_i(t)+R_i(t)} \ge 1 \tag{1.16}$$

Merger the first and third items of the left on the inequality, that

$$(\alpha+1)\delta_i(t) + \frac{\alpha}{T_i(t)+R_i(t)} \ge 1 \tag{1.17}$$

Then $\delta_i(t) \ge \frac{1}{\alpha+1} - \frac{\alpha}{(\alpha+1)(T_i(t)+R_i(t))}$, when $t \to \infty$, $\lim_{t\to\infty} \frac{1}{T_i(t)+R_i(t)} = 0$ and α is a finite integer, so there are

$$\lim_{t\to\infty} \delta_i(t) = \frac{1}{\alpha+1}$$

As can be seen from the above analysis, with the operation of the network over time, the network and the nodes converged at the Nash equilibrium point gradually, the two sides return to equilibrium. For the time $t \to \infty$, even the network gradually closed to the most advantage point of the overall performance, it will not affect the balance of return for various participants.

4.4 The application of model in forwarding process

This section will introduce how to use the game model for forwarding data packets by node to make the decision-making. Under considering the delay, we can do a better balance for the energy consumption of wireless sensor networks.

The previous routing algorithms of wireless sensor networks assume that when the node receives the data packets of other nodes in the network and requests its forwarding, the node will unconditionally accept the request and forward the data packet. In DR-G model, however, the node will priority to consider its own interest, and determine whether to forward packets through the decision-making function of the node forwarding.

To ensure that the data packet of the node is transmitted toward Sink node, in the network initialization phase, each sensor node adjust the distance between itself and the Sink nodes according to the received initialization message sent by Sink node, and set their level, while the Sink node is in the most "shallow" layer of the network (i.e., hop-count = 0). Adoption of this mechanism has the following advantages,

1. To guarantee a source node sends sensor data to Sink node directionally;
2. To adapt to characteristics of rapid changes in wireless sensor network topology. When the node failure, its child nodes can rapidly select the other nodes in the same floor as the parent node, without additional routing overhead;
3. Selected routing paths avoid routing loop issue.
4. Network topology is more stable. As shown in Figure 1.5.

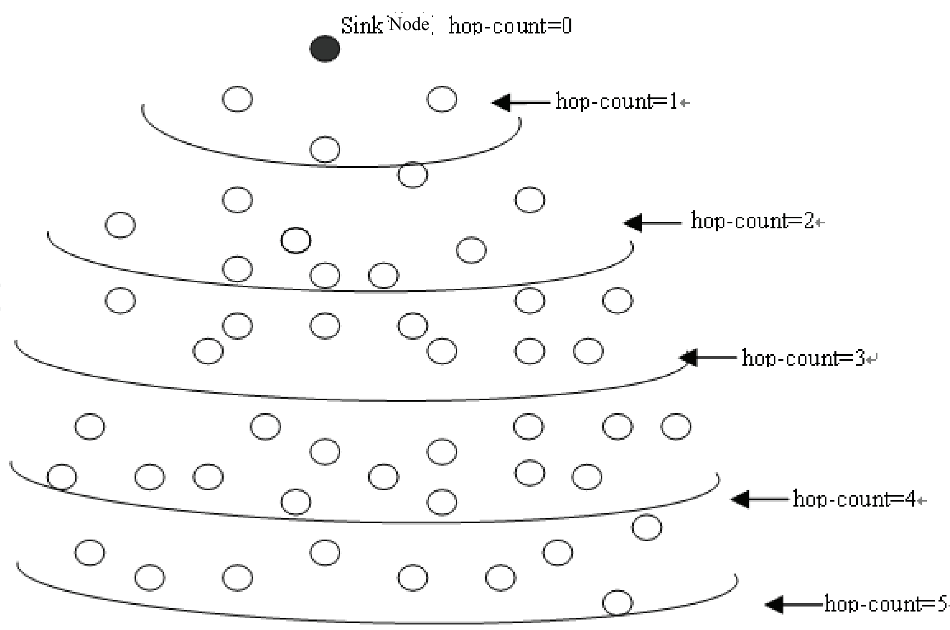


Fig. 1.5 Schematic diagram of layered wireless sensor network

For any one node in the network, the object requesting it to send the data packet includes two aspects: the data packet from the upper layer of the routing protocol, required to send to the other nodes in the network; the data packet which other nodes in network request for this node.

1. Send own data

When the node has demands for sending the data, first of all to send the request message to its previous direction neighbor nodes, the so-called previous direction is the nodes in wireless sensor network which is more shallow than their level, while the deeper nodes is not conducive to transmit data packets toward the Sink node due to the farther distance from the Sink nodes. After the previous direction neighbor nodes receive the message for requesting data, the node does the forwarding decisions according to the game model DR-G. The neighbor nodes which agreed to forward will returns a value of the feedback information with a utility function to the node requesting to send data. The node will choose the neighbor nodes of largest utility for data transmission. After data transmission, the node will have an additional one to $T_i(t)$, while the neighbor nodes of forwarding the data plus one to $R_i(t)$.

2. The other nodes request for forwarding data

When the node i receives the forwarding request of data packet, the first to determine by using the node forwarding decision-making function adding delayed compensation, if the output is 1, the node i will sent back a information of agreeing to forward data packets to the requesting node, and incidentally add the value of $U'(T_i(t), R_i(t))$ in this information. After receiving data packets needed to be transmitted and forwarding successfully, it will plus 1 to the value of $R_i(t)$, while the node which requests to forward data packets will plus 1 to its value of $T_i(t)$. If the output $\Delta'(T_i(t), R_i(t))$ is 0, then the node will refuse to forward packets for the network.

We can see from the above procedure, the node using the DR-G model to do the decision-making of forwarding is with full autonomy. When a node on the path aware that it has forwarded too much data packets for the network, the cost of the node for the utility function is too large, then the node will refuse to forward data packets, which can prevent leaving networks prematurely because of their large own energy consumption, which will also affect the normal data packet forwarding. At the same time, the introduction of delay compensation makes the node to forward data for the network during decision-making process, thus ensuring the data packet transmitted in real time.

5. Simulation and performance comparison and analysis

Through the front of the narrative, we know that wireless sensor networks consist of a large number of tiny sensor nodes deployed in the monitoring region, and forming a network system of multi-hop, self-organization by the methods of wireless communication. As the system is relatively complex, the study of wireless sensor networks is not easy to use the method of experimental analysis. TinyOS provides a powerful development language NesC, a comprehensive component library and network protocol stack. It is a architecture of component based, can quickly achieve a variety of applications, and use mainly in wireless sensor networks. In this chapter, we use the simulation tools TOSSIM embedded in the TinyOS to simulate, and do the performance of comparative analysis mainly from these two aspects of energy consumption and delay.

We use the application simulation platform TOSSIM whose open-source is based on TinyOS, and compare this reliable data fusion model RA-G to the classical data fusion routing DD and TEEN in wireless sensor networks in performance simulation. The operating system of experimental background is the virtual environment Cygwin of UNIX running on the Windows platform. In this section, we compare the data fusion model RA-G to the classical data fusion routing DD and TEEN in wireless sensor networks in performance simulation to measure the performance of RA-G.

Figure 1.6 compares the average energy consumption of the three methods in the network having 100 nodes in 2000s. As can be seen, in the beginning, the energy consumption of the integration model RA-G based on game theory is almost similar with DD and TEEN. However, with the operations of network, DD and TEEN gradually higher than the energy consumed by RA-G, such advantage will increase as the size of the network which becomes more apparent. This is mainly due to with the increases in network size, the interested proliferation of DD algorithm, the enhancement of multi-path and a cluster reconstruction work which require all nodes in the whole network to participate in TEEN algorithm will consume a large amount of energy. While in the RA-G, the energy consumption is mainly used by the node of participating target perception and needed to collect and integrate data, thus the average energy consumption rise marginally. Thus, RA-G can also well adapt to the changes in network size.

Figure 1.7 shows the comparison of the number of survival nodes in three methods with the simulation time of 1000s. When the simulation reaches 450 seconds or so later, the nodes of TEEN algorithm die quickly. As can be seen, the energy balance method of TEEN algorithm has played a certain role in energy balance, but the price is a little higher. In the DD, due to after increasing transmission delay in the shortest path, the data collected will forward along this path to the Sink node, which leads to the energy consumption between the nodes in network is extremely unbalanced, so the death rate of the node is faster. In the RA-G, the problem of the energy balance is fully taken into account. The results can be seen from the comparison, RA-G fusion model can effectively extend the network's normal working hours, to achieve the purposes of energy balance.

Figure 1.8 compares the real-time performance of RA-G model to DD and TEEN. Each curve is the average delay of data for the three method transfer under different network size when

the running time is 1000s. Can be seen from the figure, with the increases of network size, the delay in DD and RA-G shows a rising trend, which is the same principle of the average energy consumption. Because the larger the network size, the path returning to Sink node for the data packet-by-hop is longer, and the delay in the transfer process will have a corresponding increase naturally.
However, since TEEN uses a hierarchical structure of the network for data fusion method, the time waiting for the cluster head's fusion is mainly delay, which is determine by the number of the node from the cluster. Although DD algorithm is use the enhanced shortest delay path for the data forwarding, the network is a better real-time performance in the early, so the data packet which forwarded through the enhanced path will get to the sink

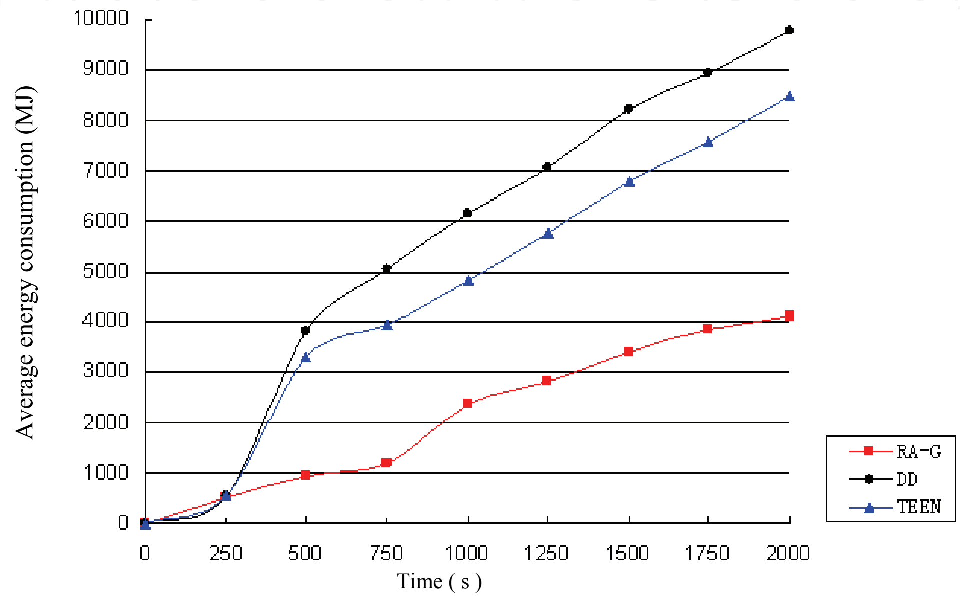


Fig. 1.6 Average energy consumption comparisons

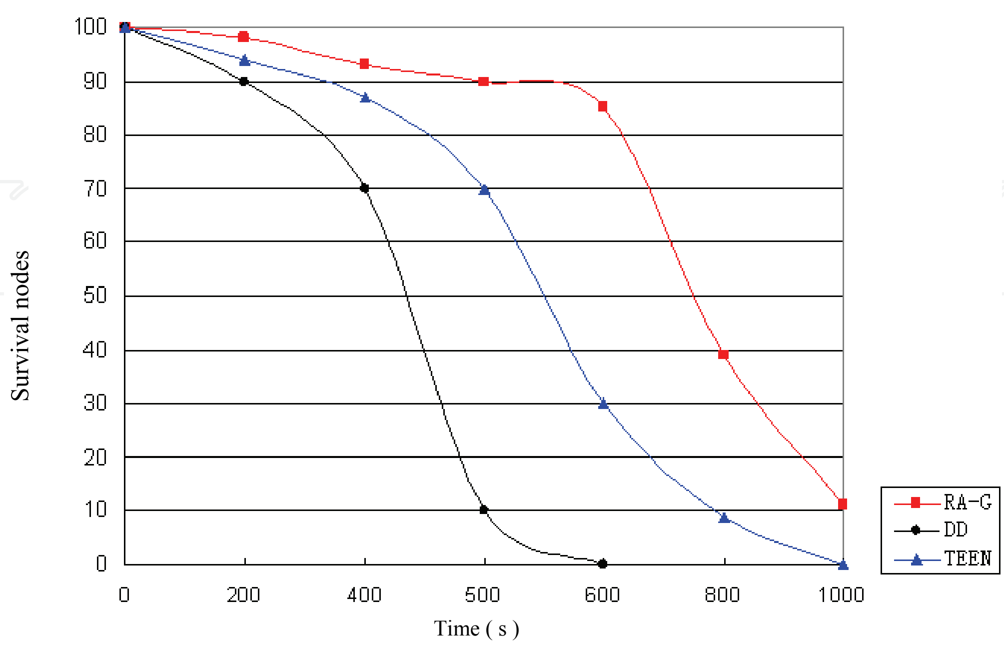


Fig. 1.7 Comparison of the number of survival nodes

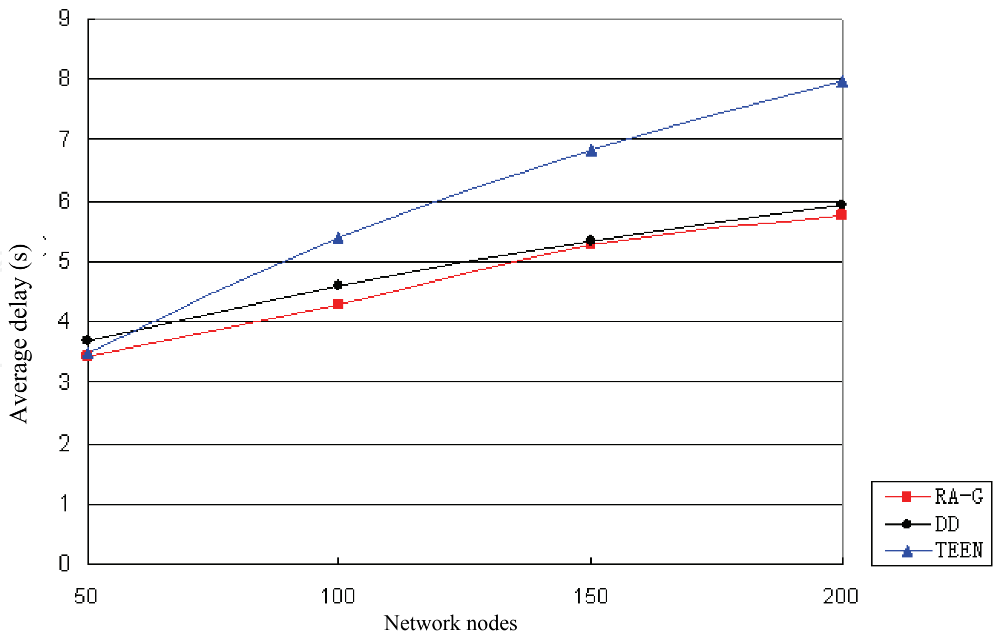


Fig. 1.8 Comparison of three methods delay

node with the shortest delay. However, with the network operations, the nodes on the enhance path consumed the energy too fast so that the lowest delay path can no longer continue to assume the task of forwarding data packets, the network had to choose another sub-optimal path to transfer data. The number of nodes which may be involved in data packet transmission is reduced, that will result in the delay become longer for data packet forwarding after the network operated for a period of time. So, taking into account the long-term stable operation of the network, DD algorithm does not highlight the real-time performance. Among the three methods, DD algorithm has large power consumption, and there is no mechanism for balanced energy consumption, the network's life cycle is shorter than TEEN and RA-G. The TEEN curve increases as the network grew rapidly. It can be concluded by observing and analyzing, that there is a delay less from the cluster head forwards the data packet to the sink node in TEEN algorithm. In the RA-G fusion mechanism, the data packets are forwarded to the sink node through multi-hop. According to game model to determine the process of forwarding, then the node use utility function to conduct merit-based routing. During this period it will bring some data packet transmission delay, the TEEN algorithm does not involve multi-hop data packet forwarding. So, TEEN data packet transfer delay is less than RA-G. But this is at the expense of a cluster head node's energy consumption. In the TEEN, the time waiting for the cluster head's fusion is always longer, because after the cluster head node allocated time slot to the cluster members, whether the members of the node want to send data or not, the other nodes are waiting for their time slot to sending data. This would give the system the too much of unnecessary delay. This trend will be more evident as the number of network nodes is increasing. As the network operation, due to TEEN need to do the cluster reorganization and the head cluster rotation in the whole network periodically, and each reorganization of cluster need to broadcast the new threshold, which will bring a lot of energy consumption to networks, in particular the head cluster node has a heavier burden. From the figure 1.12, we can see the death rate of the nodes of TEEN is faster than the RA-G in the latter part of the mechanism in the network. It has a negative impact for the reliability of the network. The accelerated death of the nodes lead to the network does not work, and the real-time reliable performance of a whole network degrades. While the RA-G can use GA-G fusion model in the group management node to dynamically determine the waiting time of regulation, and data packet forwarding game model DR-G can well balance energy consumption of each node in network while considering the delay. And multi-layer fusion mechanism can greatly reduce the traffic load of the network, effectively extend the life cycle of the network, and thus the data packet transmission delay can be stability in a long period.

From the above analysis we can see that in the network, the energy and latency are two interdependent and mutually constraining factors, only one aspect to be considered is not enough. RA-G fusion model consider both tow aspects at the same time and using the idea of game theory to build a balance model, effectively improve the network's overall performance.

6. Summary

This chapter primarily focuses on a reliable structure of data fusion RG-A of wireless sensor networks. Wireless sensor networks as a major form of mobile computing and treatment, so its position can not be replaced by other networks. Study on the Reliability about the Routing protocol for wireless sensor networks, which is the key to ensure that access to network robustness and reliability. It has a very high value and research value.

RG-A integration model is built based on game theory model for data fusion layer by layer. Nodes and network can be seen as rational actors and the two aspects of a conflict in game. Their utility function according to rational reasoning, through the game to balance the network parameters of the various constraints, so as to achieve a state of balanced, eventually achieved the purpose that to balance a real-time network and energy expenditure of the node. Not only improved the energy efficiency of the network but also to meet the target / event monitoring system for real-time reliability requirements.

7. Reference

[1] Ren Fengyuan and Huang Haining, "Wireless sensor networks." Software transactions. Vo1.14 (No.2): 1148-1l57, 2003.

[2] Estrin D, Govindan R., Heidemann J., Kumar S. Next century challenges: Scalable coordinate in sensor network.In Proc.of the 5th ACM/IEEE International Conference on Mobile Computing and Networking, 1999, 263-270.

[3] C.Y Chong and S. Kumar, "Sensor networks evolution, opportunities, and challenge." Proceedings of the IEEE. vol. 91, 1247-1256, 2003.

[4] Ma Zuchang, Sun Yining and Mei Tao, "Summary of wireless sensor networks." Communications transactions. 35 No. 4, 2004.

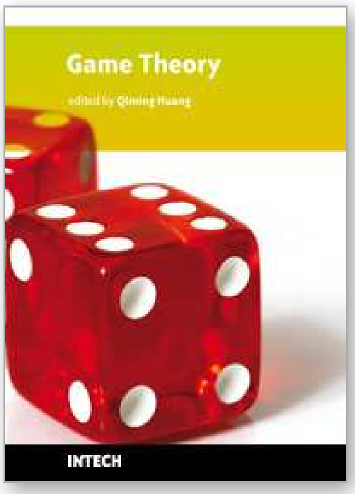
[5] Akyildiz I.F, Su W, Sankarasubramaniam Y and Cayirci E, "A survey on sensor networks." IEEE Communications Magazine.40(8):102-114, 2002

[6] L. Hester, Y. Huang, O. Andric, A. Allen, P. Chen. "A Self-Organizing Wireless Network." Computer Communications and Networks, IEEE. 364-369, 2002.

[7] Intanagonwivat, R.Govindan,D. Estrin. Directed diffusion: a scalable and robust communication paradigm for sensor networks. Proceedings of ACM MobiCom'00, Bostun,MA, 2000,56-67.

[8] N. Bulusu, J. Heidemann, D. Estrin, "GPS-less low cost outdoor localization for very small devices", Technical report 00-729, Computer science department, University of Southern California, Apr. 2000.

[9] A.Savvides,C-C Han,aind M.Srivastava, "Dynamic fine-grained localization in Ad-Hoc networks of sensors," Proceedings of the Seventh ACM Annual International Conference on Mobile Computing and Networking(MobiCom), pp.166-179, July 2001.
[10] Jamal N. Al-Karaki Ahmed E. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey." IEEE Personal Communications. Vol. 11, Issue: 6 pp. 6- 28, Dec. 2004.
[11] Kulik J, Heinzelman W R. Negotiation-based protocols for disseminating information in wireless sensor networks. Wireless Networks. 2002, 8 (8) :169-185.
[12] W. Heinzelman, J.Kulik, and H. Balakrishnan, "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks," Proc. 5th ACM/IEEE Mobicom Conference (MobiCom'99), Seattle, WA, pp. 174-85, August, 1999.
[13] Heinzelman W, Chandrakasan A, Balakrishnan H.An application specific protocol architecture for wireless microsensor networks.IEEE Transactionson Wireless Communications. 2002,(10):660-670
[14] A. Manjeshwar and D. P. Agarwal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," 1 st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, April 2001.
[15] W. Heinzelman, A. Chandrakasan Communication Protocol for Wireless and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00),January 2000.
[16] W. Heinzelman, "Application-Specific Protocol Architectures for Wireless Networks," Ph.D. Dissertation, Massachusetts Institute of Technology, June 2000.
[17] A. Manjeshwar and D. P. Agarwal, "APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks,"Proceedings International Parallel and Distributed Processing Symposium(IPDPS 2002), pp. 195-202, 2002.
[18] S. Capkun, M. Hamdi, J. Hubaux, "GPS-free positioning in mobile ad-hoc networks", Proceedings of the 34th Annual Hawaii International Conference on Svstem Sciences, pp. 3481-3490, 2001.
[19] Y. Xu, J. Heidemann, D. Estrin, Geography-informed energy conservation for ad hoc routing, Proceedings ofACM MobiCom'2001, Rome, Italy, July 2001.
[20] B Chen, K. Jamieson, H. Balakrishnan, R. Morris, "SPAN: an energy–efficient coordination algorithm for topology maintenance in ad hoc wireless networks", Wireless Networks, Vol. 8, No. 5, Page(s): 481-494,September 2002.
[21] Zhang Weiying, "Game Theory and Information Economics." Shanghai People's Publishing House. 2001:55~78.
[22] 39 Jean-Jacques Laffont and David Matimort, "The Theory of Incentives." China Renmin University Press. 2002, 6.
[23] Hart, O. and B.Holmstrrom, "Theory of Contracts in Advances" Economic Theory :fifth world congress,edited by T.Bewley.Cambridge University Press. 1987.
[24] R. R. Brooks, P. Ramanathan, and A. Sayeed. Distributed Target Tracking and Classsifcation in Sensor Networks. Proceedings of the IEEE, 2002.
[25] T. He, S. Krishnamurthy, J. A. Stankovic, and T. Abdelzaher. An Energy-Effcient Surveillance System Using Wireless Sensor Networks. In MobiSys'04, June 2004.
[26] T. He, C. Huang, B. M. Blum, J. A. Stankovic, and T. Abdelzaher.Range-Free Localization Schemes in Large-Scale Sensor Networks.In MOBICOM'03, September 2003.
[27] R. Stoleru, T. He, J. A. Stankovic, and D. Luebke. A High-Accuarcy, Low-Cost Localization System for Wireless Sensor Networks. In SenSys'05, November 2005.



Game Theory
Edited by Qiming Huang

ISBN 978-953-307-132-9
Hard cover, 176 pages
Publisher Sciyo
Published online 27, September, 2010
Published in print edition September, 2010

Game theory provides a powerful mathematical framework that can accommodate the preferences and requirements of various stakeholders in a given process as regards the outcome of the process. The chapters' contents in this book will give an impetus to the application of game theory to the modeling and analysis of modern communication, biology engineering, transportation, etc...