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A QoS-based Dynamic Scheduling Middleware of Wireless Multimedia Sensor Networks

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Abstract. QoS guarantee in Wireless Multimedia Sensor Networks is considered. QDSM (QoS-based Dynamic Scheduling Middleware) is proposed. In QDSM, firstly a combined service QoS Model is established, secondly the application QoS requirement is interpreted and delivered to WMSNs by this model. Besides, a node schedule algorithm (NSA) based on QDSM is designed. Suitable type and number of sensor nodes can be scheduled. According to users' requirements, data can be collected, processed and transmitted by NSA. Mathematical proof and simulation results show the effectiveness of QDSM in QoS guarantee.

Keywords: Wireless Multimedia Sensor Networks; QoS; middleware; node schedule

1. Introduction

Kinds of multimedia data like video and audio can be perceived by WMSNs(Wireless Multimedia Sensor Networks) to meet various of users' requirement, so it has been used widely in some fields like environment monitor, object tracer and e-home etc.. However, on the one hand, the data collection, process and transmission in these applications are complicated and need more bandwidth, on the other hand, some WMSNs' traits like energy consume, mobility and instability, can result in data loss and bad QoS guarantee. Above all, how to meet users' needs and give users a better QoS guarantee in WMSNs, become a key problem.

Middleware can shield some network differences and provide a unified platform for users, it can be used to solve the above mentioned problem. The middleware is divided into two sorts by Paper[2], active and passive middleware. Network can be configured by the active middleware according to users' needs. For example, middleware SOMM[3] is designed by service-oriented method in order to meet various of service requirements and provide QoS guarantee. Middleware VSAM[4] is used in distributed and heterogeneity sensor network, sensor nodes are selected and data are transmitted to sink nodes. The positive middleware can change its own configure to adapt the network's difference. Take middleware Senceive[5] as an example, a search interface and a network configure interface are given for users,and the task of network management and data sense are divided. Though some services for users can be provided by Senceive but QoS guarantee is less.

In WMSNs, there are lots of data to be sensed and processed. The in-time requirements are higher too. The flexibility and stability of active middleware make it work well in WMSNs. The active middleware QDSM is proposed in this paper. In QDSM, firstly a combined service QoS Model is established, secondly the application QoS requirement is interpreted and delivered to WMSNs by this model. Based on QDSM, NSA is designed. Suitable type and number of sensor nodes can be scheduled to collect, process and transmit data that users' need by NSA.

The rest of this paper is organized as follows. Related work is presented in section 2. In section 3, the QDSM middlewere and its nodes schedule algorithm is presented. Section 4 gives the experiment result and its analysis and the conclusion is drew in section 5.

2. Related work

In WMSNs, the nodes in or out the network can result in network topology changes often. The nodes resources are limited too. QoS guarantee becomes very difficult. QoS guarantee in WMSNs by middleare has become a hot problem of research in or out of the broad. Some research work has a lot of progress[6]. There are still many difficult problems[7]. For example, lack of usual QoS framework, the effective nodes selection algorithm etc.. QDSM is proposed in this paper based on related paper.

2.1 Work Environment

The WMSNs' architecture can be divided into three sorts, flat, cluster-based and multilayer architecture. The cluster-based architecture is used in this paper.it is easier than the multilayer one and can process the data conveniently, so lots of energy can be saved for WMSNs. In this architecture, different kinds of nodes are included in one cluster, for example, audio sensors, video sensors and scalar sensors. The task of data collection and transmission is finished by all kinds of sensors in the conduct of QDSM.

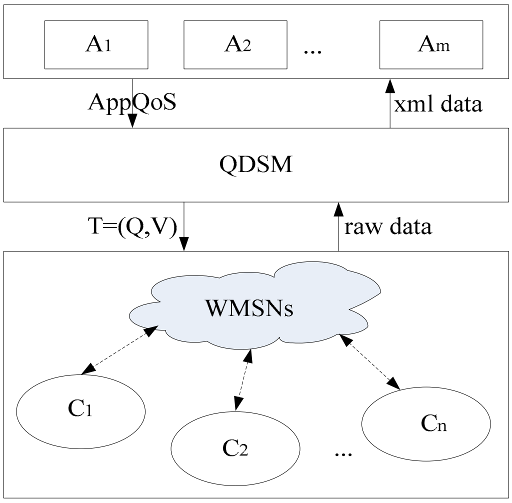

Figure 1. The WMSNs architecture based on QSDM

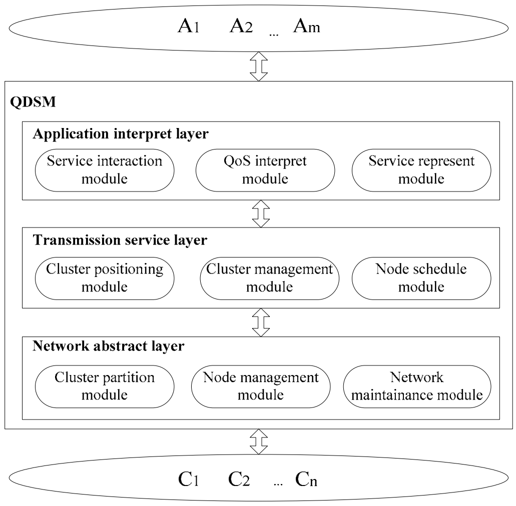

Figure 2. The detailed design of QDSM

As shown in Figure 1, QDSM is between the application layer and the WMSNs, $A_1, A_2, ...A_m$ represent various of QoS applications, $C_1, C_2, ...C_n$ represent the clusters. Firstly the users' QoS requirements are delivered to QDSM. Secondly users' QoS requirements can be interpreted and expressed as $T = (Q, V)$, where T are users' QoS requirements, Q is the concrete QoS and V is the value of each Q. Finally the data are expressed as XML and delivered to users.

3. The design of QDSM and NSA

3.1 The Combined Service QoS Model

In order to meet users' requirements, it is need to establish a combined service QoS model. In this model, the users' QoS requirements are defined as the combine of many two-tuples, $T = (Q, V)$. Suppose there are n kinds of users QoS requirements, they can be represented as the set of T, shown in (1).

$$A\_QoS_k = \{T_1, T_2, ...T_i ...T_n\}, T_i = (Q_i, V_i) \tag{1}$$

where A_QoS_k is a concrete kind of QoS requirrment, Q_i represents the kind of QoS is i, V_i is the value of Q_i, meaning the percentage to meet users' requirements.

3.2 QDSM

QDSM is between the application and the WMSNs, it can provide service for users as well as shield the detail configuration of WMSNs. By departing the whole architecture into many layers, the usres' needs can be delivered to QDSM and the QDSM to schedule the WMSNs, all layers work coordinately to finish the task of data collection, amalgamate and transmission. The detailed design of QDSM is shown in Figure 2.

QDSM includes three layers, the application interpret, transmission service and network abstract layer. Users' requirements can be gotten and represented into two-tuples $T = (Q, V)$ by the application interpret layer. It also can deliver the finally results to usres. There are three modules in this layer, service interaction, QoS interpret and service represent module. The service interaction module is used to provide an interface for users. QoS interpret module confirms which kinds of nodes to sense data with Q. The acquired data are presented to users by service represent module.

Transmission service layer is the core of QDSM. It selects clusters and sedules nodes. Cluster positioning, cluster management and node schedule module are in this layer. The cluster positioning module maintains the information of all clusters in WMSNs. It communicates with cluster's head in order to achieve data. The clusters that applied to provide service are also decided by cluster positioning module. The cluster management module manages the nodes information in each cluster. NSA is generated and used by node schedule module int order to get data.

WMSNs configuration is abstracted and heterogeneity is shielded in network abstract layer. It includes Cluster partition, node management and network maintenance module in this layer. The cluster partition module departs the nodes into many different clusters and selects a head for each cluster. Node management module maintains each clusters' status information, including the position of clusters and the node types in cluster. The whole networks' connection is managed in network maintenance module. If there are some nodes in or out WMSNs, this module can regulate dynamicly.

3.3 NSA

NSA selects suitable nodes according to users' QoS requirements in order to provide service. Firstly, according to the Q in $T=(Q,V)$, the node type is confirmed and the candidate clusters set SC is selected. Secondly, candidate clusters are sorted by the number of nodes. Then with the value of V in $T=(Q,V)$, the number of nodes can be determined.

- NSA
  1) Get the candidate cluster set SC, $SC=(C_1,C_2,...C_k)$, $1\le k\le m$;
  2) Get cnt_i, the number of nodes that can provide service of each C_i in SC;
  3) Sort the clusters according to cnt_i and get the candidate clusters set SC', $SC'=(C_{i+j,...}C_{i,...}C_{i-j}), i>j>1$;
  4) For each kind of QoS requirement, select cnt numbers of nodes to provide service.(the best cnt will be gotten in lemma 2).
- Proof

Lemma 1 According to Q in $T=(Q,V)$, k clusters can be gotten to provide services.

Proof Get the map between QoS type and node set $Q_i\rightarrow(S_{i1},S_{i2},...,S_{ii})$, compare each map $(S_{k1},S_{k2},...,S_{ki})$ of Q_k to the node set $(S_1,S_2,...,S_i)$ in C_i. if $S_m=S_n, m\in(k1...ki), n\in(1...i)$, then the value of C_s increases 1.If $C_s>0$. Select C_i as a candidate culster and k increases 1. The final k is the number of candidate clusters.

Lemma 2 There are N numbers of nodes can provide service for Q_i, the best N can achieved.

Proof N numbers of nodes are used to provide M numbers of service, the achievements can be shown in matrix w.

$$w=\begin{bmatrix} c_{11} & c_{12} & \cdots & c_{1m} \\ c_{21} & c_{22} & \cdots & c_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ c_{n1} & c_{n2} & \cdots & c_{nm} \end{bmatrix} \tag{2}$$

where c_{ij} is the achievements of i nodes are used to provide j kinds of service. If node i can provide j kinds of service, then set x_{ij} =1, else x_{ij} =0. Suppose each node can only provide one service, then in the constraint condition of (3), The achievements of p can be shown as (4).

$$\begin{cases} \sum_{i=1}^{n} x_{ij}=cnt & j=1...m \\ x_{ij}=1,0 & i=1...m, j=1...n \end{cases} \tag{3}$$

$$p = \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} \cdot x_{ij} \tag{4}$$

The best p is the value of (4).

Theorem Suitable nodes can be selected and QoS guarantee is provided by NSA.

Proof It can be seen from lemma 1, the candidate clusters for service can be gotten. In the candidate cluster, by lemma 2, the best numbers of nodes can be selected. NSA can give a QoS guarantee to users.

4. Simulation

In order to prove the effectiveness of QDSM, the simulation is done in Fedora 9.0, using ns2 v2.28 as simulation tool.The parameters and their values are shown in tabel 1.

Comparison is done in SOMM[4], VSAM[5] and QDSM. Throughput, network delay and loss rate are selected as parameters of QoS. The results can be seen from Figure 3 to Figure 5.

Table 1 Simulation parameters and initial values

Parameter	Initial value	Parameter	Initial value
scene (m2)	300×300	initial energy	40
audio nodes	20	route selection algorithm	AODV
vidio nodes	20	queue length	30
scalar nodes	20	data rate(packets/s)	1-60

Figure 3 shows the loss rate of QDSM, SOMM and VASM. In WMSNs that used QDSM, the loss rate's maximum value is only 0.3% and is relatively stable. While in WMSNs that used SOMM and VASM, the loss rate is relatively high and tends to increase as time.

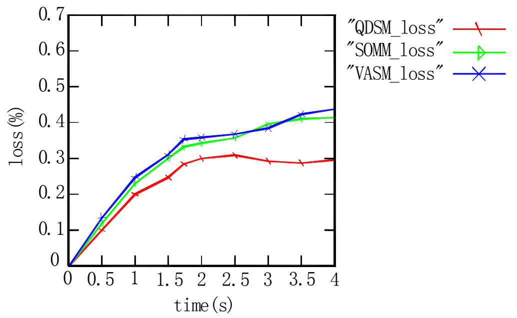

Figure 3. The loss rate of QDSM, SOMM and VASM

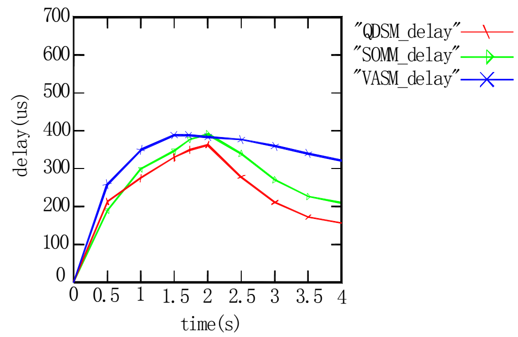

Figure 4. The network delay of QDSM, SOMM and VASM

Figure 4 shows the differences in network delay of QDSM, SOMM and VASM. The network delay is lower in WMSNs with QDSM than with SOMM and VASM.

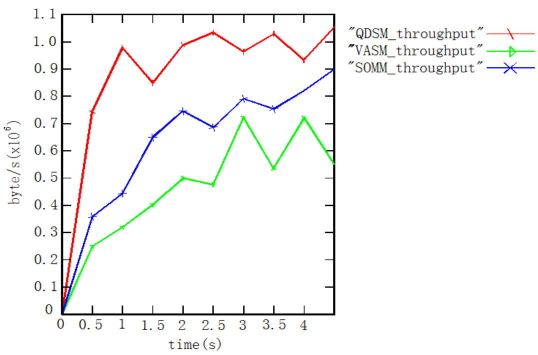

Figure 5. The throughput of QDSM, SOMM and VASM

In Figure 5. It is clearly that the throughput in QDSM are higher than SOMM and VASM.

Above all, QDSM can achieve the goal of QoS guarantee. It can provide better service for users in WMSNs.

5. Conclusion

QoS guarantee in WMSNs has been considered in this paper. QDSM has been provided and NSA has been given based on QDSM. Suitable nodes can be selected by NSA. Kinds of data can be collected, processed and transmitted by QDSM. Proof for NSA has been given too. The effectiveness of QDSM has been shown by simulation.

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