Connecting Sensor Networks with TCP/IP Network

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Abstract. Wireless sensor networks cannot have meaningful work without connecting with TCP/IP based network. In this paper, we analyze and compare all the existing solutions for connecting sensor networks with TCP/IP network, then based on the analysis result we present the basic design principle and key idea for connecting sensor networks with TCP/IP network. After comparing with related researches we claim that our solution can cover most of the benefits of related researches. [1]

1 Introduction

In the desired 4G paradigm, all kinds of heterogeneous wireless networks and current existing IP based Internet should be integrated into one pervasive network to provide transparent accessibility for users. Sensor networks as a family member of wireless networks should also be integrated. In the new appeared pervasive computing paradigm, by using ubiquitous sensor networks as the underlying infrastructure, middleware which is considered as the key solution to realize the ubiquitous computing paradigm has been invested in many famous research projects, such as Gaia, Context Toolkit, Aura, TOTA, etc. Ubiquitous sensor networks play an important role in our daily life to provide the seamless pervasive accessibility to users. Therefore, in this paper we propose a novel gateway based approach to connect sensor networks with TCP/IP network. In next section, we present related researches. In section 3, presents the key idea and detailed description of our *Virtual – IP Gateway*. In section 4, we present the comparison with related researches, and conclude this paper in section 5.

2 Related Work

***Gateway-based approach*:** This is the common solution to integrate sensor networks with an external network by using *Application-level Gateways* [1] as the inter face. Different protocols in both networks are translated in the application layer as

[1] Dr. Jinsung Cho is the corresponding author.

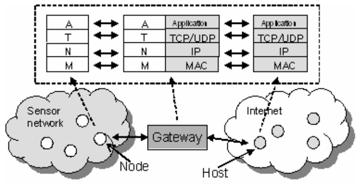

Fig. 1. Application-level Gateway

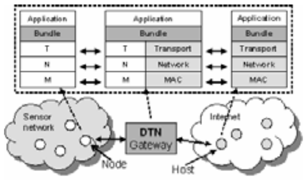

Fig. 2. Delay Tolerant Network

the Figure 1 shows. The advantage is: the communication protocol used in the sensor networks may be chosen freely. However, the drawback is: Internet users cannot directly access any special sensor node. Another research work, *Delay Tolerant Network* [2], also follows this *Gateway-based approach*. The key different point from [1] is that a *Bundle Layer* is deployed in both TCP/IP network and non-TCP/IP network protocol stacks to store and forward packets, as Figure 2 shows. It is very easy to integrate with different heterogeneous wireless networks by deploying this *Bundler Layer* into their protocol stacks. But the drawback also comes from the deployment of *Bundle Layer* into existing protocols, which is a costly job.

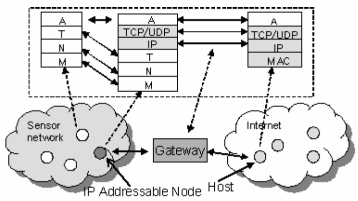

Fig. 3. TCP/IP overlay sensor networks

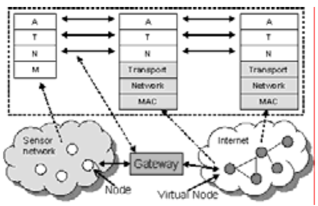

Fig. 4. Sensor networks overlay TCP/IP

***Overlay-based approach*:** There are two kinds of overlay-based approaches for connecting sensor networks with TCP/IP network: 1) *TCP/IP overlay sensor networks*; 2) *sensor networks overlay TCP/IP*. Research work in [3] provides a solution to implement IP protocol stack on sensor nodes which is named as **u-IP**. The key advantage is: Internet host can directly send commands to some particular nodes in sensor networks via IP address. However, this **u-IP** can only be deployed on some sensor nodes which have enough processing capabilities. We show **u-IP** approach in Figure 3. The *sensor networks overlay TCP/IP* is proposed in [4]. As Figure 4 shows, sensor networks protocol stack is deployed over the TCP/IP and each Internet host is considered as a virtual sensor node. By doing so, Internet host can directly communicate with sensor node and Internet host will process packets exactly as sensor nodes do. The problem of [4] is: it has to deploy an additional protocol stack into the Internet host, which brings more protocol header overhead to TCP/IP network.

3 Virtual – IP Gateway

After having these aforementioned analyses, we create our key idea Virtual – IP Gateway: Basing on Node-Centric or Location-Centric communication paradigm, mapping the node label (ID) or location address with IP address in gateway. The IP address will not be physically deployed on sensor node, but just store in gateway as a virtual IP address for Internet users. In this *Virtual – IP Gateway*, there are two major components to translate packets for both sides, as Figure 5 shows: *1) TCP/IP Network -> Sensor Networks (T->S) Packet Translation*, translating packets from TCP/IP network into the packet format of sensor networks; *2) Sensor Networks -> TCP/IP Network (S->T) Packet Translation*, translating packets from sensor networks into the packet format of TCP/IP network. The packet format of original *T->S Packet* has four major fields: 1) *User IP*, used to represent the IP address of user's who sends this packet; 2) *Sensor IP/Gateway IP*, used to represent the destination of this packet, which can be the gateway IP address or some special sensor node's IP address; 3) *Q/O*, used to represent packet type: *Query Command* or *Operation Command*; 4) *Complicated/Simple Data Request / Operation Command*, used to represent the real content that is carried by this packet. The packet format of created *T->S Packet* has the following four major fields: 1) *Gateway ID/Location*, used to represent the ID or location address of Gateway, which sends the packet to sensor networks; 2) *Sensor ID/Location*, used to represent the ID or location of data source; 3) *Q/O*, used to represent packet type: *Query Command* or *Operation Command*; 4) *Complicated/Simple Data Request / Operation Command*, used to represent the real content that is carried by this packet. The *Query Command* is used to request data from sensor networks, it can be as simple as query data just from one special sensor node, or it can be as complicated as query data from many sensor nodes at the same time. *Operation Command* is used to remote control one special sensor node's working status. Similarly, the packet format of *S->T Packet* also has four major fields: 1) *Sensor ID/Location*, used to represent the ID or location of data source; 2) *Gateway ID/Location*, used to represent the ID or location address of Gateway, which is the destination of this packet; 3) *D/A*, used to represent packet type: *Data Packet* or *Acknowledgement Packet*; 4) *Data/Acknowledgement*, used to represent real content carried by this packet. The packet format of created *S->T Packet* has the following four major fields: 1) *Gateway IP*, used to represent the IP address of Gateway, which sends the packet to TCP/IP network; 2) *User IP*, used to represent the IP address of receiver's; 3) *D/A*, used to represent packet type: *Data Packet* or *Acknowledgement Packet*; 4) *Data/Acknowledgement*, used to represent real content carried by this packet. A *Node ID/Location Address* is the node ID or location address of a sensor node. A *Data Information* is a description about what kind of data can be provide by this sensor node. An *IPv6 Address* is the assigned IP address for this special sensor node. *Virtual – IP Gateway* will actively collect *Node ID/Location Address*, *Data Information* for all sensor nodes, and also actively assign *IPv6 Address* for these sensor nodes. All these information are stored in a database which physically locating in the *Virtual – IP Gateway* and mapped with each other.

TCP/IP Network -> Sensor Networks Packet Translation: After receiving packets from TCP/IP network, there are two ways to translate them into the packet format that used by sensor networks: 1) *Data Information Based Discovery*; 2) *IPv6 Address Based Discovery*. Gateway will analyze these received packets based on the field "*Q/O*" to categorize them into *Query Command* and *Operation Command*. If a packet is an *Operation Command*, then gateway can base on the *Sensor IP* to search

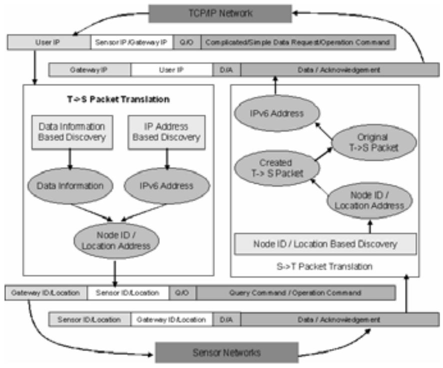

Fig. 5. Architecture of virtual – IP gateway

the database to find out the corresponding *Node ID/Location Address* of this sensor node through the mapping between *IPv6 Address* and *Node ID/Location Address*. If a packet is a *Query Command*, then gateway can base on *Complicated/Simple Data Request* to search the database to find out the corresponding *Node ID/Location Address* of this sensor node through the mapping between *Data Information* and *Node ID/Location Address*. After knowing *Node ID/Location Address* of this sensor node, we can easily create the new packet for sensor networks. Before sending created packet to sensor networks, we backup this new *T->S packet*, and map it with the original *T->S packet* in gateway. These saved packets will be used when we translate packets that come from sensor networks into the packet format of TCP/IP network.

Sensor Networks -> TCP/IP Network Packet Translation: After receiving the *S->T Packet* from sensor networks, gateway first bases on packet's *Sensor ID/Location* to find out the created *T->S Packet*, then through the mapping between the created *T->S Packet* and the original *T->S Packet*, gateway can easily find out the original *T->S Packet*. By analyzing the original *T->S Packet*, gateway can get the *User IP*, and then create the new *S->T Packet*. Before sending this new *S->T Packet*, gateway will delete the corresponding original and created *T->S Packets* to save the storage space of the database.

4 Comparison with Related Researches

A table based comparison with related researches is essentially necessary to prove that our solution can cover most of the benefit of related researches, as Figure 6 shows. After the integration of sensor networks and TCP/IP network, we can still keep the consistency with the IP based working model by hiding the sensor ID. Because in the view of Internet users, the sensor networks is IP based, they don't need to know which kind of routing protocol is used in sensor networks. Since we only deploy virtual IP addresses in gateway, rather than bring any modification to sensor networks protocols, sensor networks can still freely choose the optimized routing protocol which is *Node-Centric* or *Location-Centric* based. Furthermore, Internet users can easily and directly access some special sensor nodes via *virtual IP ad*

	Application level gateways	Delay Tolerant Network	TCP/IP overlay sensor networks	Sensor networks overlay TCP/IP	Virtual IP
Consistent with Internet working model	No	No	Yes	No	Yes
Transparent for Internet users	Yes	Yes	Yes	No	Yes
Freely choose routing protocol in sensor networks	Yes	Yes	No	Yes	Yes
Directly accessibility some special sensor node	No	No	Yes	Yes	Yes
Easy to integrate different sensor networks	No	Yes	No	Yes	Yes

Fig. 6. Comparison with related researches

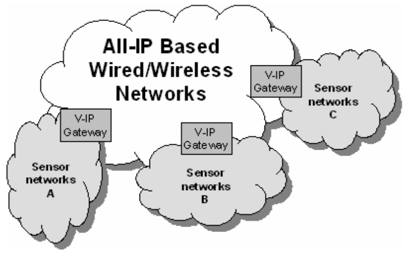

Fig. 7. Integration of Several sensor networks

dresses. Sensor networks which are physically located in different locations may use totally different routing protocols for their specific applications, as Figure 7 shows. If these sensor networks have gateways which have *virtual IP address*es, then it is very easy to integrate them into one virtual network without modification on existing protocols.

5 Conclusion

Sensor networks as a family member of wireless networks should be integrated with TCP/IP network to provide meaningful services. In this paper we present a new solution to connecting ubiquitous sensor networks with TCP/IP network. By comparison with related researches we claim that our new solution can cover most of the benefits of related researches.

Acknowledgement

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