Grid Middleware for Invivo Sensor Nodes

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***Abstract*—Energy limitation, heterogeneity of hardware, increase in node temperature, absence of software reusability-are major problems in existing middleware for body sensor networks. In this paper, we have proposed an event based grid middleware that solves all these problems using distributed resources. In our multi-hop communication, we have used lightweight rendezvous routing algorithm on publish/subscribe system of event based communication. To faciliate software re-use and application development, modified OSGI has been implemented in our middleware architecture. We have considered our grid middleware on a scenerio of cancer treatment with join operations of hyperthermia, chemo-therapy and radio-therapy with invivo sensors.**

I. Introduction

Modern diagnosis system has been evolved to equipe human being with advanced health-service. Invivo sensors have come up to contribute in this field with its support in miniature, complex operation as implanted in human body[1].

Hyperthermia[2] is a prominent method in cancer treatment. In hyperthermia, body cells are heated to a certain temperature for a certain amount of time. Radiotherapy, chemotherapy are also popular cancer treatment methods. The join operation of hyperthermia, radiotherapy, chemotherapy [2] is considered to be the best way in cancer treatment. Temperature scheduling among cells is the most important issue in this case. Human cells are very sensitive and if temperature goes above a threshold value, cells will be in danger. Temperature scheduling is an important issue in such join operation in cancer treatment.

Thermal aware routing algorithms [3], [4], [5], [6], [7] have been proposed to solve temperature scheduling in invivo sensor nodes. But, the main problem is the complexity overheard insufficient for lightweight invivo sensor nodes. As temperature grows, more temperature is generated and more battery life is wasted. We need a lightweight routing algorithm for invivo sensor nodes.

Middleware [8], [9] for body sensor nodes [10] has been popular for last few years. Middleware for invivo sensor nodes has not been imagined so far. For cancer treatment, when we have heteregeneous invivo sensor nodes (deployed for hyperthermia, radiotherapy and chemotherapy), middleware can be better solution. As we need lightweight solution for miniature nodes, we need to distribute operation, temperature and power consumption. This has motivated us toward a grid approach on middleware [11],[12] for invivo sensor nodes.

We have proposed a grid middleware that practices event based communication [13], [14] in invivo sensor nodes. It consists of a lightweight rendezvous routing algorithm. The algorithm schedules temperature for invivo sensor nodes deployed for join operation of hyperthermia, radiotherapy and chemotherapy. In middleware design, we have used an OSGI-based architecture.

This paper is organized as follows. Section 2 discusses the need for a grid based middleware for invivo sensor nodes. In section 3, we have proposed the OSGI based middleware architecture and lightweight rendezvous algorithm. Section 4 presents performance evaluation with problem scenario and results achieved. Section 5 shows related works and we have given our future works in section 6.

II. Need for a grid middleware of invivo sensor nodes

Invivo sensor nodes are of heteregeneous hardware. They are deployed for critical, sensitive and complex applications. With improvements in technology, smart invivo sensors with heteregeneous services are becoming popular in various treatments. Middleware hides underlying operating system and heteregenosity of physical devices from application layer. But, with the case of invivo sensor nodes, reducing both energy dissipation and thermal effects are major concerns. Grid middleware can be a good solution as it distributes services among invivo sensors and reduces both enegery dissipation and thermal effects. Grid middleware can be beneficial for invivo sensor in following ways

A. Scalability

Scalability means that it can support a large number of invivo sensor nodes. Middleware services are distributed, there is almost no centralized approaches. Decisions and state information -these are locally viewed, in stead of global state. Network bandwidth, memory are used efficiently.

B. Interroperability

Grid middleware is designed to support heteregenosity of components over network. It is language and platform independent. It can cope with dynamic environment of components of distributed systems and both fixed and mobile devices can join and leave at rum time.

C. Reliability

QoS and reliability requirements can be resolved with grid architecture. Different invivo sensors may have different requirements. Grid middlware may have generic support for these requirements. For example, a generic MAC framework

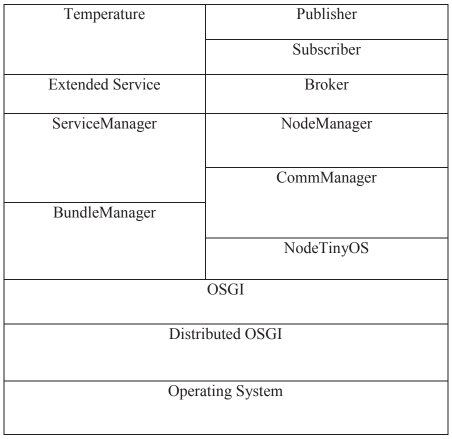

Fig. 1. Architecture of the proposed middleware

can be integrated in middleware architecture. Invivo sensor nodes can use any of the MAC protocols depending on their specific criteria like energy limitation etc. It can have reliability options like 'best efforts' and 'timely and guarranted'

III. Proposed middleware

A. Architecture

Proposed grid middleware consists of several layers. Application layer is in the uppermost position on the architecture. Services like blood pressure, temperature calculation can be implemented as OSGI bundles in this layer. To add a new node to the system, OSGi bundle implementing nodes service should be installed in this layer. Inside the middleware, installation involves invoking of loadNode from ServiceManager.

The service location of nodes bundle and serial identifier are important parameters in this invocation. Next comes the middleware layer consisting of layers namely: ServiceManager, CommManager, NodeTinyOS, OSGI and DistributedOSGI . ServiceManager is in the uppermost and Distributed OSGI is the lowermost layer of all middleware layers. ServiceManager allows application bundles to get node objects by using services. This layer allows upper application layer to install and uninstall nodes. It sends beacon message to other nodes to update their status and forwards incoming message to application bundle so that they can process information. NodeManager layer allows nodes to send and receive 802.15.4 message by using services from CommManager layer. A set of open interface can be defined in this layer for each node, allowing interoperability between devices of different hardware vendors. CommManager layer sends/receives message service to upper layer through serial port. This layer uses the service provided by NodeTinyOS layer made of TinyOS OSGI packages. This layer helps in registering receivedmessage. Application bundle registers incoming message with NodeManager. Message comes to CommManager, NodeTinyOS one after another. It is then sent to ServiceManager that checks messages source to forward to application bundle. The lowermost layer is the DistributedOSGI layer. It allows that multiple peers with OSGI framework can communicate in a way that makes them like in a large OSGI framework.

B. Proposed Lighteweight Rendezvous Routing Algorithm

We are given three types of invivo sensor nodes namely publisher, broker and subscriber. Each set consists of publisher/publishers, subsciber/subscibers and publisher/publishers and some sets will co-exist together to schedule temperature in human cells. Let, S, P, and B be set of subsciber, publisher and broker respectively. Let, R be a rendezvous node in gateway. Broker B sends subscription information and failure notification (of temperature scheduling) to rendezvous node.

We have proposed lightweight rendezvous routing algorithm for temperature scheduling in invivo sensors. Publisher/Subscriber based event based communication is deployed for this network.

Algorithm 1 Lightweight Subscription

for all i such that $0 \leq i \leq N$ **do**
  Subscribe S to any broker B with event E
  Corresponding broker B sends subcription information to rendezvous Node
end for

In lightweight subscription method(Algorithm 1), each subscriber node (i) is subscribed to broker for specific event. At the time of subscription, broker node sends subscription information to rendezvous node.

Algorithm 2 Lightweight Publish

for all i such that $0 \leq i \leq N$ **do**
  Publish event E_j with publisher P to broker B
  if subscriber S for event E_j is found **then**
    do not send information to Rendezvous
  else if subscriber S for event E_j is not found **then**
    send message(that S is not found) to rendezvous node.
  end if
end for

In lightweight publish algorithm(Algorithm 2), each event (i) is published through a publisher node to broker. If the broker finds corresponding subscriber node or nodes, it disseminates temperature among them. For all events, if at least one subscriber node is not found, notification is sent to rendezvous node from corresponding broker node.

IV. Performance Evaluation

A. Problem Scenario

In cancer treatment, join operation of hyperthermia, radiotherapy and chemotherapy has become the most prominent. It depends on the temperature generated on human cells. If the temperature is below a threshold temperature, hyperthermia enhanches performance of radio-therapy and chemo-therapy.

But, if it is above the threshold, human cells become sensitive and it becomes dangerous to human health. We are considering implanted sensor nodes reflecting temperature scheduling in join operation of cancer hyperthermia, radiotherapy and chemotherapy.If the temperature of a node (publisher) is increased above threshold, it will commumicate broker node to disseminate temperature to subscriber node or nodes. If the temperature dissipation is not performed successfully, remote gateway node should be notified by broker node. Energy dissipation is also considerable. The more the temperature is generated, the more battery power is exhibited. To extend the battery life of invivo sensors, energy reduction is important.

B. Results

Parameter	Description	Value
i	Number of Experiments	8
N	Number of Total Nodes in the network	10
N_B	Number of Event Brokers	1-5
N_S	Number of Event Subscribers	2-5
N_P	Number of Event Publishers	2-5
E	Number of Events	2-5
E_P	Number of Events Per Publisher	2-5
E_S	Number of Events Per Subscriber	1-5

Table 1: Events, subscribers, brokers, publishers used in simulation

We have performed our extensive simulation in JAVA simulator. Table 1 shows the number of experiments, events and nodes used. Event type is unique and it occours when the temperature of node exceedes threshold value of $46\,^{\circ}$C.

Parameter	Description	Value
P_B	Broker's power	5mW
P_S	Subscriber's power	2mW
P_P	Publisher's power	2mW
P_B	Node's exhibiting power	2mW
P_S	Node's receiving power	2mW
P_B	Node-rendezvous node(power)	2mW
P_B	Node's exhibiting temperature	1mW
P_S	Node's receiving temperature	1mW
P_B	Node-rendezvous node (temp.)	2mW
C_p	Threshold temperature	$46\,^{\circ}$C
K	Thermal Conductivity	0.498 [J/ms $^{\circ}$C]
T_b	Fixed Blood Temperature	$37\,^{\circ}$C
d	Max density	1040 kg/m3

Table 2: Simulation environment

In our simulation environment (Table 2), a node's temperature is increased $1\,^{\circ}$C if it sends or receives a packet. When a node sends packet to a rendezvous node (in subscription or failure notification),it's temperature is increased $2\,^{\circ}$C. A node exhibits 2mW power when it sends or receives packet. But,it sends packet to rendezvous node, it exhibits 5mW power.

P	S	B
3	2	5
2	3	5
3	3	4
3	4	3
4	3	3
4	4	2
5	4	1
4	5	1

Table 3: Permutation of publisher, subscriber and broker nodes in simulation

Each experimental set consists of 10 nodes. Table 3 shows permutation of 10 different nodes of type publisher, subscriber and broker. In each experiment, we have considered four steps:

(a) Subscribe: subscriber nodes subscribe to events

(b) Publish best case: when broker needs the least packet transfer to dissiminate temperature to broker node.

(c) Publish worst case: when broker needs the maximum packet transfer to find subscriber node or nodes to dissiminate temperature.

(d) Publish lost case: when broker uses the maximum packet transfer in search of subscriber node or nodes and it then sends notification message to rendezvous node.

Fig 2, 3, 4, 5 show these four steps of four experimental sets. In Fig 2, experimental set consists of 3 publishers, 2 subscribers and 5 brokers.

In subscription (Fig 2(a)), 2 subscribers S subscribe to 5 broker nodes B who send subscription information to rendezvous node R .

S_T=20 unit

S_E=45 mW

In publishing(best case)(Fig 2(b)), 3 publisher publish events to 3 broker who will dissiminate temperature to 2 subscribers.

PB_T= 12 unit

PB_E=24 mW

In publishing(worst case)(Fig 2(c)), 3 publisher publish events to 5 broker who requires more packet transfer to find the appropriate subscribers.

PW_T= 20 unit.

PW_E= 40 mW

In publishing(lost case)(Fig 2(d)), 3 publisher publish events to 5 broker who requires more packet transfer to find the appropriate subscribers.

PL_T= 30 unit

PL_E= 65 mW

In publishing (best case),

total generated temperature= S_T+ PB_T= 32 unit

total consumed energy= S_E+ PB_E= 69 mW

In publishing (worst case),

total generated temperature= S_T+ PW_T= 40 unit

total consumed energy= S_E+ PW_E= 85 mW

In publishing (lost case),

total generated temperature= S_T+ PL_T= 50 unit

total consumed energy= S_E+ PL_E= 110 mW

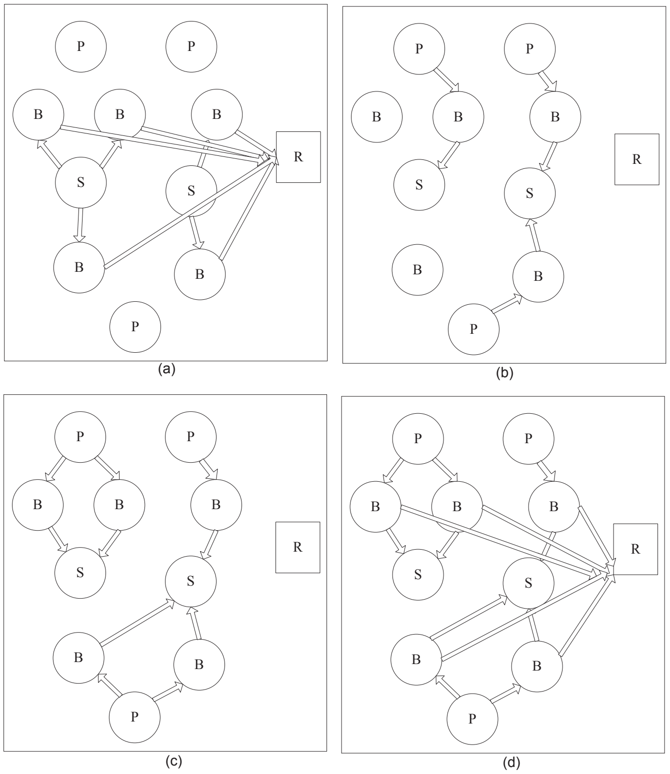

Fig. 2. a.Subscribe, b.Publish (best case) c.Publish (worst case) d.Publish (lost case)Publisher:3, Subscriber:2 and Broker:5

In Fig 3, experimental set consists of 3 publishers, 2 subscribers and 5 brokers. In publishing (best case), total generated temperature= S_T + PB_T = 38 unit, total consumed energy= S_E + PB_E = 61 mW. In publishing (worst case), total generated temperature= S_T + PW_T = 50 unit, total consumed energy= S_E + PW_E= 85 mW. In publishing (lost case),total generated temperature= S_T + PL_T = 60 unit,total consumed energy= S_E + PL_E= 110 mW.

In Fig 4, experimental set consists of 3 publishers, 3 subscribers and 4 brokers. In publishing (best case), total generated temperature= S_T + PB_T = 28 unit, total consumed energy= S_E + PB_E= 60 mW. In worst case, total generated temperature= S_T + PW_T =32 unit,total consumed energy= S_E + PW_E=68 mW. In lost case, total generated temperature = S_T + PL_T = 40 unit, total consumed energy= S_E + PL_E =88 mW

In Fig 6, we see the thermal effects of proposed lightweight rendezvous routing algorithm on experimental sets of Table 3. Figure 7 shows the energy dissipation effect on the same by the proposed routing algorithm.

V. Related Works

Temperature aware routing algorithms [3], [4], [5], [6], [7] have been proposed to generate temperature in less amount in routing process. But, these suffer from complexity overhead. Existing middleware for body sensor network [15], [16] use gateway approach where body sensor nodes contact with a

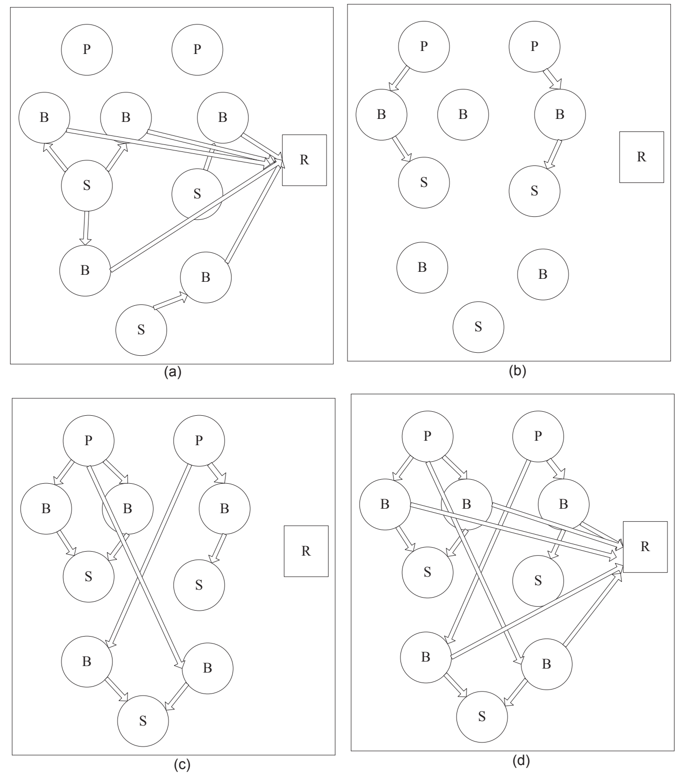

Fig. 3. a.Subscribe, b.Publish (best case) c.Publish (worst case) d.Publish (lost case)Publisher:2, Subscriber:3 and Broker:5

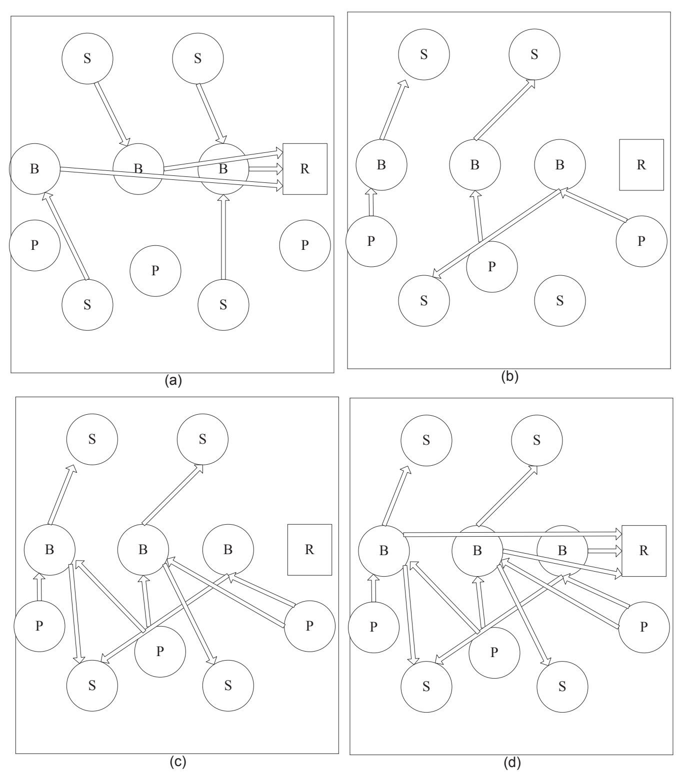

Fig. 4. a.Subscribe, b.Publish (best case) c.Publish (worst case) d.Publish (lost case)Publisher:3, Subscriber:4 and Broker:3

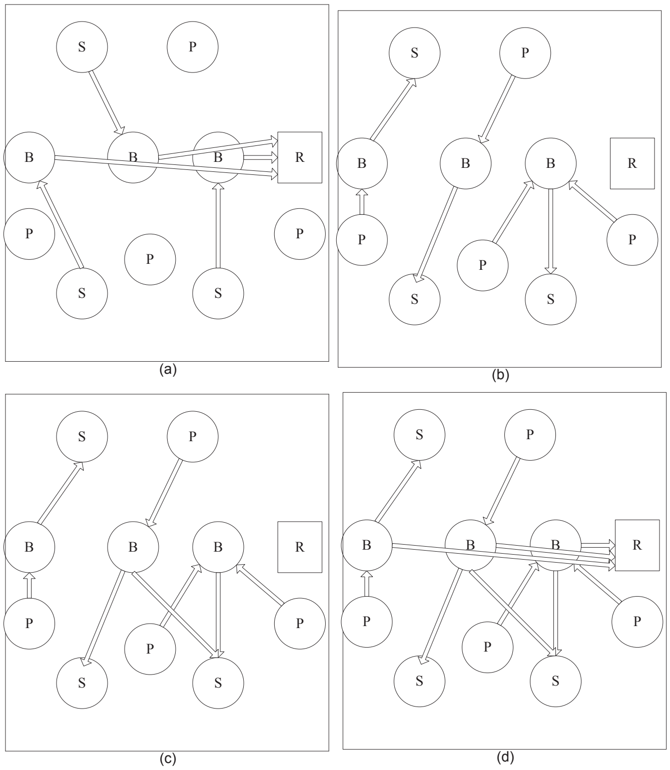

Fig. 5. a.Subscribe, b.Publish (best case) c.Publish (worst case) d.Publish (lost case)Publisher:4, Subscriber:3 and Broker:3

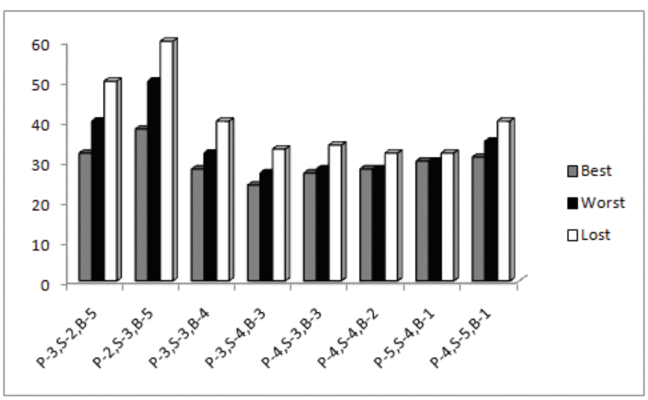

Fig. 6. Temperature effects by lightweight rendezvous algorithm

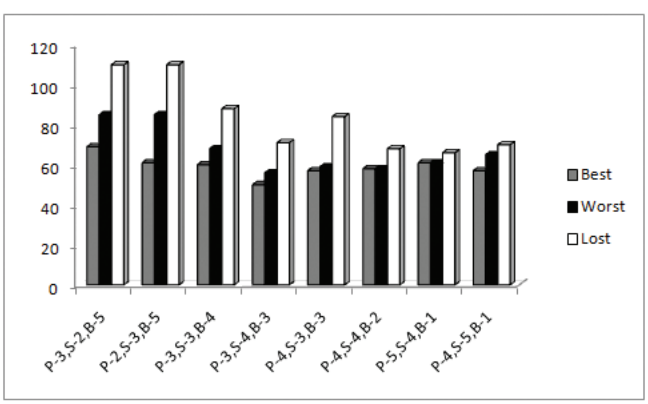

Fig. 7. Energy dissipation in lightweight rendezvous algorithm

gateway device. But, grid middleware approach on invivo sensor nodes has never been thought so far. [1] discusses about prospects of sensor network in cancer hyperthermia treatment without any conclusive proposal.

VI. Conclusion

In this paper, we have presented a grid middleware with lightweight rendezvous routing algorithm. Our routing algorithm schedules temperature in invivo sensor nodes to facilitate the join operation of hyperthermia, radiotherapy and chemotherapy of cancer treatment. We have considered experiemental sets consisting of 10 nodes. In future, we need to consider issues like scalability, node orientation with it. Overlay broker network routing is an overhead for invivo sensor nodes, we use new approach of lightweigh rendezvous algorithm as an alternative. In future, we have a plan to include a lightweight broker network routing solution to the grid middleware.

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