Research Statement

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My research is primarily focused on Wireless Personal Area Network (WPAN) and Distributed Systems (DS).

Research on WPAN

Currently, we are working with IEEE 802.15.4, which is standard for low power consumption, low—cost and **L**ow data-**R**ate **W**ireless **P**ersonal **A**rea Network (LR-WPAN). The standard is a landmark in the attempt to bring ubiquitous networking into our lives. With the introduction of this standard, short-range, low-rate wireless personal area networks are poised to take the world in a way observed never before.

To use this standard in a multi-hop network, ZigBee proposed a *Tree* routing algorithm, which several advantages over other routing algorithms. After a great success of IEEE 802.15.4/ZigBee network in **P**ersonal **O**perating **S**pace (POS), it has also been tried to apply in multi-hop large network. But the Tree routing algorithm exhibits several problems for large network. One of the major problems of tree routing is that it limits network depth. Moreover, in some cases, the network can not grow because of the exhaustion of address in some part while the other part is very poorly loaded.

To avoid this problem, we have provided several solutions. First, we have provided a unified address borrowing scheme which can be easily applied to grow the network and overcome the address exhaustion problem by borrowing unused addresses. In this scheme, a node X will be allowed to join a network at a node Y even if Y has exhausted its available addresses by borrowing a address from a different node which is having free address and assigning it to the requesting node X. The new node X will physically be attached to node Y and will have the physical address of some other node with addition of very small routing table.

Secondly, we have observed that, in some other network configuration, the network may need to grow beyond the maximum breadth because of the asymmetric nature of the physical area. So, we have provided a unified address reorganizing scheme which can be easily applied to asymmetric tree network. In this scheme a node X will be allowed to join a network at a node Y even if Y already has maximum number of children by 'address reorganization'. This scheme can be used in part of the network where the network wants to grow in breadth rather than in depth. This happens when the depth at that part of the network is less than L_m (maximum network depth) due to the asymmetric physical structure.

We have also proposed a new tree routing algorithm, together with a prefix-code based flexible addressing scheme. Devices using this algorithm need not also have any routing table. Route to a destination can still be determined using some simple mathematical and/or logical calculations. Proposed addressing scheme allows a device to have variable number of child devices. We have also shown that this flexible mechanism can be used to allow larger number of devices in the network.

ZigBee also proposed a Mesh routing algorithm where a huge burst of control packets are generated during the route discovery. We have made several optimizations to control the number of control packets produced for route discovery.

Currently, we are trying to handle other issues that arise in WPAN such as, power-aware routing, reliable message delivery, real time data transfer etc.

Research on DS

In my Ph. D. thesis, I have proposed middleware-based architecture to design and implement low-latency Distributed Systems (DS). The approach is built on two fundamental concepts *distributed caching* and *load balancing*.

I designed and implemented three architectures based on CORBA's *event service*, *object wrapper* and *interceptor*. Finally, I integrated them to form a unified object caching architecture that can be used to cache different types of remote objects with a little modification of existing code. This approach is based on applications specific cache consistency policy, per process caching, object graph based data shipping and replication management. I have applied this architecture on applications with different types of system requirements (such as *strong consistent*, *casual consistent* and *read only* system) and have made a performance comparison among them. I have demonstrated that the proposed architecture of caching results in improved performance for applications that exhibit a reasonable amount of read operations.

I have then provided a 3-tier on-demand, adaptive, transparent load balancing architecture for state-full CORBA object caching system and implemented it. The proposed architecture uses a combination of *interceptor* and *object wrapper* to intercept requests at various points with minimum overhead that improves efficiency significantly. Instead of a centralized load balancer, balancing of load is performed entirely in distributed manner, which introduces the system as a fault-tolerant one. Servers can always be added to the load balancing server group without restarting the system. Within the load balancing server group, consistency is maintained using *write-through-cache-invalidate* method.

While existing systems apply caching and load balancing mechanisms individually to improve performance and reliability, this work demonstrates that if we combine these mechanisms to form a framework then that can be effectively used to develop low latency and reliable scalable distributed systems.

Other Research Areas

Currently, we are also working on some other areas such as reconstructing minimum spanning tree in dynamic harsh environment, optimization problems etc.

Reconstructing a minimum weighted spanning tree in a highly dynamic asynchronous distributed network is a well known problem in the field of distributed computing. Node failure (or recovery) and Link failure (or recovery) triggers topological changes in the system. We have described a distributed algorithm to reconstruct the minimum spanning tree after link failure. The modified algorithm improves total number of message communication by $2E'$ (where E' is the number of edges of the fragment that contains the root of the minimum spanning tree) assuming no other topological changes occur during the execution of the algorithm.

Research on RFID

Radio Frequency Identification (RFID) systems have emerged as an efficient and cost effective solution for tracking objects containing passive RFID tags. The choice of passive RFID tags is due to its low cost and simplicity of implementation. The problem is to identify objects containing passive RFID tags. If there are multiple objects in the range of a reader, they all send their ID to the reader simultaneously in response to the reader's query. This leads to collision at the reader end and no tag is identified leading to the wastage of bandwidth and increase in total delay in identifying all objects.

We have presented efficient collision resolution protocols which can be used in a situation where tag reader attempts to obtain unique identity of the tags in its range in real time. The approach concentrates on different performance parameters regarding the singulation process and It also analyzes the performance of different anti-collision algorithms on the basis of different performance parameters such as total number of messages sent between tags and readers during singulation process, total time for singulation etc.

Research on Optimization

Hardware/Software partitioning is one of the most important issues of co-design of embedded systems, since the costs and delays of the final results of a design will strongly depend on partitioning. We have developed an algorithm based on Particle Swarm Optimization to perform the hardware/software partitioning of a given task graph for minimum cost subject to timing constraint. By novel evolving strategy, we have enhanced the efficiency and result's quality of our partitioning algorithm in an acceptable runtime. Also, we have compared our results with those of Genetic Algorithm (GA) on different task graphs. Experimental results show the algorithm's effectiveness in achieving the optimal solution of the HW/SW partitioning problem even in large task graphs.

We have also applied PSO to place Wireless Access Points such a way that every location is connected by at least three access points so that we can apply triangulation to find the position of a device.