Abstract

A Wireless Sensor Network (WSN) is a new and upcoming technology that has grabbed the attention of the technical community over the last decade. It opens the possibility of numerous applications ranging from industrial to consumer use. Such is the expected impact of this technology, a mass cultural change along the lines of the Internet is predicted. A WSN is also considered as one of the most important technologies of the 21st Century. The wide interest from the technical community is largely due to the immense number of application areas enabled by this technology and the unique technical constraints that give scope for innovation (and publications). The technology has matured to a fair extent where sophisticated hardware is commercially available from leading chip manufacturers at low prices and communication protocols (software) have been ratified to allow inter operability among chip vendors. Recently, start-up companies have offered the WSN product on a commercial basis. However, the actual deployments in a business organization, worldwide, have been abysmally low and there has been no publicized deployment of a WSN in India.

We start our investigation by gathering user requirements and expectations from the technology in three areas of its applicability – agriculture, manufacturing and asset tracking. These requirements dictate the effective adoption of the technology and give us rich insights on the real world applicability of a WSN.

A wireless sensor network can be thought of as a new technical product (a black box). It has attributes and functionalities which appeal to a consumer and thus promote adoption. Technical researchers and product developers work to make these attributes better and conform to requirements of certain applications. These attributes of a WSN are accepted universally and large volumes of technical research are associated with them. The attributes are (i) ease of deployment, (ii) relaxed quality of service requirement, (iii) low data rate, (iv) routing, (v) scalability, (vi) low cost, (vii) fault tolerance and (viii) long life.

Our experiences at the application scenarios show a common theme - a) the sensing points are well defined and the need is to have an optimal relay placement strategy, b) the data communication is from the sensors to the sink and vice versa and c) the network has to have perceptions of immediate value. Our research in each of these three aspects forms the rest of the thesis.

The extant literature in deployment support of wireless sensor network is largely focused on unconstrained relay deployment where the relays can be placed at any location in the deployment area. Further, such deployments disregard the radio profile of the area of deployment. These assumptions are costly and tend to prevent the practical usage of such algorithms. *In our research we present a practical, optimal deployment scheme that develops the network topology using the received signal strength indication (RSSI) and thus takes into account the actual radio profile of the deployment area.* Our deployment scheme also adheres to rules on fault tolerance, constrained locations and scalability. In this way, our scheme is readily usable in a practical scenario.

Methodology:

- Global deployment algorithms based on minimum Steiner tree.
- Local optimal algorithm modeled using integer linear programming (ILP).
- Simulations and comparisons made using C with ILP module from GNU Linear programming Kit (GLPK).
- Network topology modeled using uniform and geometric distribution.

A planned deployment of a WSN, as done above, has certain network properties. A plot of the best path from the leaves of the network to the sink and vice-versa, considering that no relay needs to talk to another relay, reveals the network to be hierarchical in nature. In such a set-up existing routing algorithms like Ad-hoc On-demand Distance Vector (AODV) are extremely wasteful of network resources. On the other hand, a pure hierarchical algorithm suffers from its inability to support scalability and fault tolerance. *We thus develop a routing algorithm that combines the flexibility of the AODV scheme with the structure of the hierarchical network.* We show our algorithm has inbuilt support for fault tolerance and can support any network topology.

Methodology:

- A routing framework using properties of AODV and network hierarchy.
- Three algorithms designed using the framework – deterministic, probabilistic and heuristic
- Simulations and comparisons made with AODV and C_{skip} with implementation in C++.
- Network topology modeled using uniform and geometric distribution.

Having developed technical solutions, we implemented simplified versions of our algorithms on commercial wireless chips. We re-visit the asset tracking application scenario and deploy a 20

node wireless sensor network for a period of 100 hours. The deployment region is an industrial manufacturing plant and our task is to monitor the movement of fork lift trucks (FLTs) to gauge its utilization ratio. A simple deployment as above is shown to provide rich value, both in terms of management and financial. We conclude through this real life deployment, the practical applicability, the technical feasibility and the value of a wireless sensor network in the industry.

Methodology

- A20 node wireless sensor network to track the movement of FLTs in a manufacturing plant
- Compute the utilization ratios and optimize the number of FLTs needed.

Concluding Remarks

Our study of the technology has given us an intricate knowledge of the hardware, the software and the protocol stack used for a wireless sensor network. Coupled with our qualitative understanding of user requirements and application needs, we develop technical solutions for the successful adoption of a wireless sensor network. We show the technology's maturity and industry readiness by a real life deployment in an application scenario. Our study on this deployment shows managerial and financial value. Our thesis, we hope, is a stepping stone to the eventual adoption of wireless sensor networks.