

Effective topologies for the constraints set forth for biomedical
sensor networks?

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Abstract

Implanted wireless biomedical sensors have the potential to change medicine. These sensors are being thought of for several biomedical applications. These wireless sensors have the potential to converse with a computer system wirelessly. Research challenges are presented due to the need for having a biocompatible, fault-tolerant, energy-efficient, and scalable design. Figuring out how to implant these wireless sensors in humans adds additional research challenges. Wireless biomedical sensors should be ultra-safe and reliable and have nominal maintenance. In determining how to arrange the biomedical sensors, the location of the sensor nodes should be fixed and the arrangement should be pre-determined.

Chapter 1

Introduction

Wireless sensors also known as smart sensors are motivating great interest to society. Smart sensors are created by combining sensing materials with integrated circuitry are being used and well thought-out for several applications today. These smart sensors must be tiny, have low cost as well as low power. They must be tiny in that they will be scattered around any and everywhere. They must be low in cost because of the demand for so many of them and they must have low power because you do not want them attached to a large battery. The applications of smart sensors are wide-ranging that it is not possible to name all of its uses but only a few. Smart sensors can be used in military interest to deploy in combat scenarios to track troops movements, biological or chemical weapons and report if any found to protect those troops in combat. Smart sensors can be used in civilian applications as pollution detectors along beaches. Distributing the smart sensors along the shoreline and using wireless communication to send information that the sensor has picked up to a base station for further processing could accomplish this. It has been projected for these smart sensors to be used as climate control monitors in large office buildings, where the temperatures has been inconsistent. Another application, which uses smart sensors and is the basis of this paper, is biomedical applications.

1.1 What are wireless biomedical sensors?

Wireless biomedical sensors are a group of embedded smart sensors that form a network from wireless communication links; that operate within the human body to compensate for various diseases. These implanted sensors have the potential to revolutionize medicine. The smart sensors are placed in the body and communicate with a base station via a wireless interface. Applications using or taking interest in wireless biomedical sensors are artificial retina, glucose level monitors, organ monitors, cancer detectors, and general health monitors to name a few. Research challenges arise with the

inadequate power and computational capabilities of smart sensor based biological implants.

More is involved than just the triumphant display of the underlying transduction mechanisms. Sensors can react differently in vivo compared to their in vitro presentation. Due to the sensor being physically present, interaction with the biologic host such as deposition of cellular and other materials on the sensor surface, tissue response to the sensor's presence, and breakdown of the materials on the sensor can all affect the local environment thereby changing the measured quantity. Just because the sensor appears to have a high stability once implanted in the body the sensor can be unstable due to these mechanisms. The environment in which the body is in can affect a sensor's physical integrity. The packaging of a sensor, how the sensors are arranged in the body also known as the topology is an important consideration in the design and application of these devices.

Chapter 2

Existing Problems

Being that biomedical sensor networks are inimitable from other sensor network applications domains, different problems arise that need to be handled differently from other wireless sensor networks. Such problems are low power, limited computation, material constraints, robustness and fault tolerance, scalability, security and interference, and regulatory requirements.

2.1 Low Power

Regardless of the type of sensor, all wireless sensor networks have power restrictions. This is due to how small the sensors are and them being wireless. Using batteries, as power is impractical because the sensor is implanted in the body and it is not sensible to replace the battery as often as it would be needed. Solar power and vibration power provides inadequate power for continuous operation. Energy is an important factor in that it is needed to run the sensor, process the information and data communication. This energy would have to be equally dispersed and consumed among the nodes in the network. Having the power evenly dispersed allows the nodes to be revitalized all together, cutting down on the use of the bandwidth for revitalization. Another problem using biomedical wireless sensors is the heat that is dissipated from using the power. The placing of the sensor in the body has a great affect on the tolerable amount of heat that is dissipated.

2.2 Limited Computation

Computation is straightforwardly inadequate due to the restricted amount of power. The amount of computation with a biomedical sensor is considerably less than the potential of a generic sensor. Communication is costly when it comes to power because more power is used to communicate than to compute. Given that these sensors are small, a limited quantity of power and communication is essential and little power will remain for computation. Because of this constraint, one idea was to employ a data compression mechanism.

Data compression permits the exact amount of data to be transmitted in fewer bits. There are different algorithms appropriate for different applications for compressing data. In many cases, the sensor will perform periodic polling of the environment. The sensor may constantly process this data and relay the increasing readings once every five minutes. The sensor itself will probably perform some local processing of the data, large amounts of data might still be left to convey. Because energy efficiency is the key, the less data to communicate, the less power the sensor will use.

Image compression is when the images coming from the external camera will be compressed before being transmitted into the internal sensors, reducing the amount of information that needs to be transmitted through the limited bandwidth. Segmentation is used as a method for compressing these images. Segmentation works by examining and highlighting the area being compressed. Once these highlights are discovered, adjacent areas are then compared to see if any trends follow. Good quality dictates a high redundancy rate. This makes sure that the correct information is getting from the sensor to the external device and vice versa. High redundancy is expensive as well as a common technique called data fusion. Data fusion involves several nodes pooling their information together for increased computational power processing and accuracy.

2.3 Material Constraints

The actual shape of a sensor, size of the sensor and what materials are in the sensor will be restricted due to the biomedical sensor being implanted in the body. If the sensor were designed to support the eye it would have to be small enough to fit within the eye. Using the sensor as a gastrointestinal monitor, it could take the form of the pill and be taken orally. These biomedical sensors may have to be shaped and sized to curve around an eye or contain a bone or cartilage, having an impact on the sensor design and material use. The biomedical sensor has to be able to securely and successfully function in the body. The sensor nodes must be composed of biocompatible materials because the human immune system is designed to fight off foreign substances in the body. These biocompatible materials must act as a barrier between the fluids and the sensor components and not slow down the operation of the sensor. Materials are limited to ones

that are not harmfully affected by bodily fluids. Thrombosis is a condition, which occurs when the platelets in the blood begin to clot on the surface of the sensor. If the condition affects the sensors, operating is not a solution. Operating on the body should not cause harm to the sensors. Leakage of toxic or hazardous substances with the sensor should also be avoided.

Biocompatible materials must be packaged correctly and with caution for the sensor nodes. Common biocompatible materials are synthetic or biological polymers, metals, or ceramics. Glass packaging is motionless with respect to the body. It has poor thermal properties, dispersing much less heat than other materials. The remaining heat is then dispersed through part of the sensor node itself. This heat dispersion has a high chance at causing lifelong damage to the surrounding tissue. Crystalline materials have high thermal conductivity properties, which make them good for sensor packaging. Aluminum nitride is also motionless with respect to the body, which makes a reasonable choice for biomedical sensors.

2.4 Robustness and Fault Tolerance

Implanted sensors are expected to be operational for extensive periods of time. Chronically implanted sensors are expected to have years and decades of operation time. The whole network of sensor nodes should not fail just because of one sensor node. A distributed network is one way to avoid this from happening. Distributed network is when each sensor node can operate separately from its neighbors. This is so if perhaps a sensor node does not working the surrounding sensor nodes should continue working. Just like with sensor node failure, data should still be received and passed on if communication is functioning. A solution to this would be to have several small components wired together that function as a group. This is a good way to separate the malfunctioning nodes from the rest of the components in the node, as well as decreasing power consumption among the different components. Making sure that the proper data is being sent and received an idea of using checksums, as an error detection scheme is one way. Using checksums each data message travels along with a checksum value based upon the ones' complement or two's complement of the sum of the message. If the

values equal there is a high likelihood that the message was sent without loss data; if unequal the message has been tainted in transmission and needs to be sent again.

Diagnostics is another feature needed for biomedical sensors. The sensors will have to be adjusted to give the proper care to each patient. Diagnostics will be imperative for testing prototypes of these devices. Designing these biomedical sensors and implanting numerous sensor nodes will direct to more robustness than implanting one sensor node. Small, low-power sensors spread out among a large area will probably cause less damage to the tissue than one large power-consuming sensor node.

2.5 Scalability

Significant amounts of functionality are need and to achieve this many small sensors need to be placed and work in conjunction with each other. With many sensors speaking with themselves and the output device, lots of communication will be taking place, challenging the competent use of the wireless spectrum. It is still unclear to as how many sensors will need to be implanted into the body at this point but it is better to construct the sensors in the ability to amplify the number as the technology becomes more advanced than to redesign the system each time the sensor count is increased.

2.6 Security and Interference

There is no solution currently to keeping an outsider from gaining access to the sensors or the display. Encrypting all the data is to strong and to computationally severe to be practical for these uses.

2.7 Regulatory Requirements

Before human testing can begin, these prototype devices will have to meet the strict standards of patient safety. The wireless transmission of data must not hurt the surrounding tissues and the chronic functioning and power utilization of these devices must be benign. Safety must be a major phase in developing biomedical sensors.

Chapter 3

What are topologies?

Topologies, which were briefly mentioned earlier, refer to a network and the way all of its pieces connect together. This refers to the layout of the computers, printers, and other equipment hooked to the network in a building. Because cables connect these spread out computing resources together into a network, the network's topology is also a function of the way in which the cabling is ordered, whether it is arrayed in a bus, ring, or star, which are the three basic physical topologies. Recent technological advances have made unclear the peculiarity between the physical and logical arrangements; the topology selected may also influence the media-access control method, which is, Ethernet or token ring under which the network will function. A network's logical layout may differ from its physical layout. The logical topology identifies the electrical path; the physical path identifies how the cables, concentrators, and nodes are arranged.

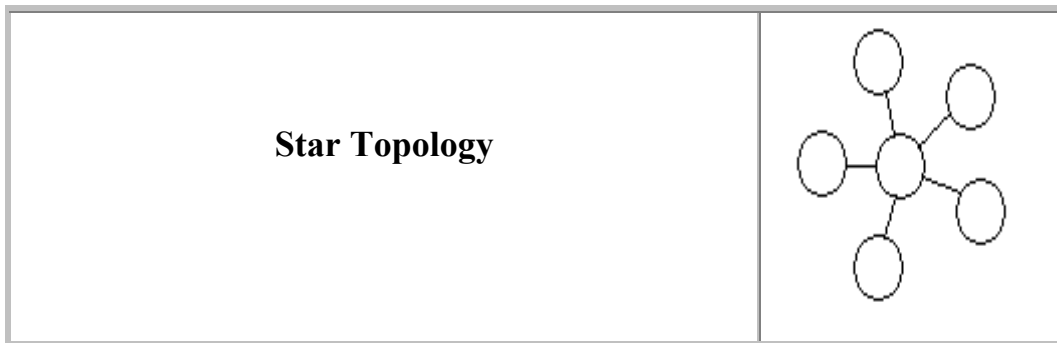
3.1 Different Types of topologies

There are different types of topologies, some which have advantages over the other. The most common topologies are the star, ring, bus, tree, and mesh topologies.

3.2 Star Topologies

Star topologies are found mostly in minicomputer and mainframe environments. They are idyllic for wide area network (WAN) applications in which outlying offices must communicate with a central office. Cascaded stars are a type of star topology that has one centralized multiport repeater, which serves as the fiscal point for many other multiport repeaters. Numerous homes use star topologies. Star topologies have a middle node called a hub. The hub is the central connection point of all the nodes. Star topologies require more than one cable because each node has to connect or attach itself to the hub.

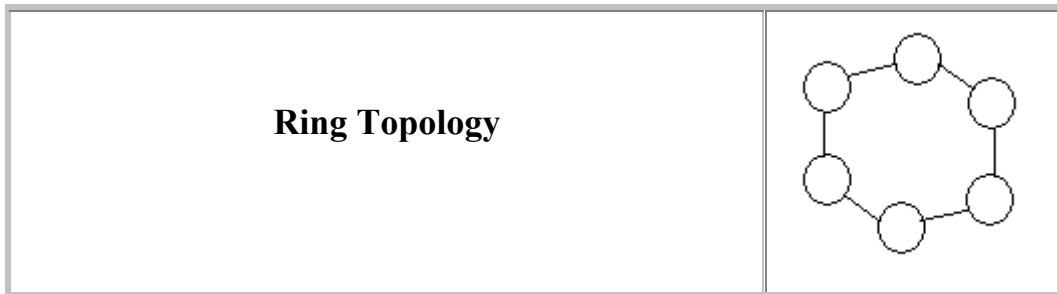
Nodes communicate across the network by passing through the hub. If one cable or node fails the whole network does not fail because the cable or node attached to the hub is not keeping the network going. It is the hub that holds the network together, so if the hub fails the whole network fails. Below is an example of what a star topology looks like. The middle circle is the hub.



3.3 Ring Topologies

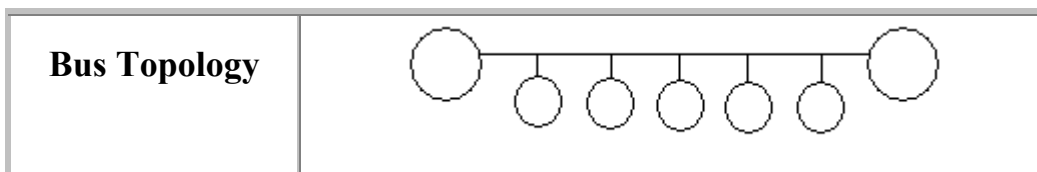
Ring topologies take the form of a ring. Their cable wires are looped to form a complete logical circle. These topologies are found in office buildings or on school campuses. The nodes must travel in the same direction, either clockwise or counter clockwise. A single cable holds this network together. Each node has two neighbors, one on each side for communication purposes. If one of the nodes fails in the network then the whole network fails because they are all sharing one cable. One type of ring is the token ring. The token ring uses an electronic signal called “token” to pass from station to station. As the token is being passed it regenerates a new token. The transmitted data over the network must wait until the token is passed to a neighboring station.

Once the token is passed it takes control of the station and places the data packet on the network. After the data has made a full circuit of ring returns to the originator and the station the token is then released for the next workstation.



3.4 Bus Topologies

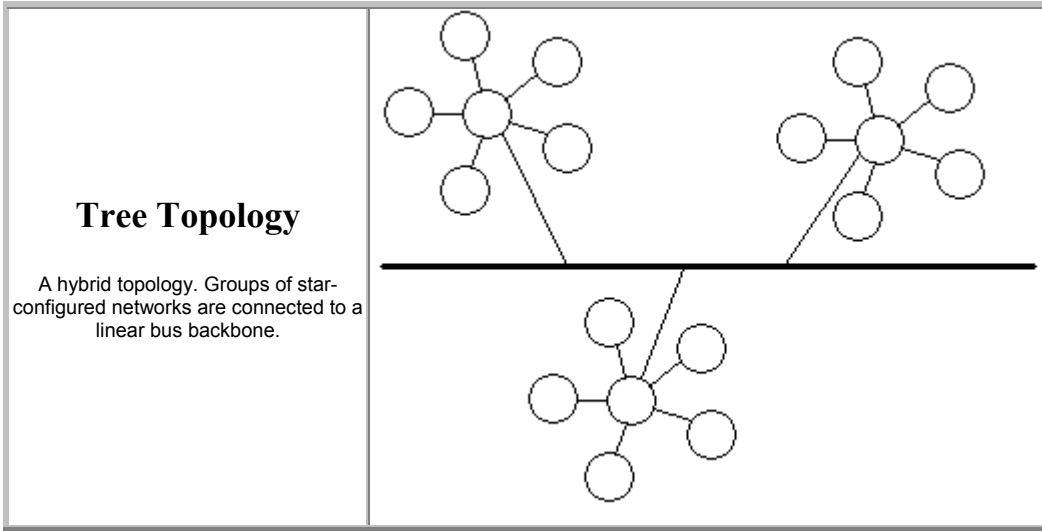
Bus topologies are attached to a single cable. Each node can only carry one message at a time. Every workstation has to know when it can and cannot transmit data using a shared medium. Each station listens in on cable transmissions for other stations. Data can only be transmitted when the cable is not busy with another transmission. A bus topology is held together by a common backbone that connects all other devices. If one node wants to communicate with another node, it sends out a broadcast message onto the wire for all the other nodes to hear but the only device that can accept and process the message is the one the message was intended for. The bus topology works best with small amounts of nodes. The downfall to having a bus topology is when the backbone fails the whole network fails.



3.5 Tree Topologies

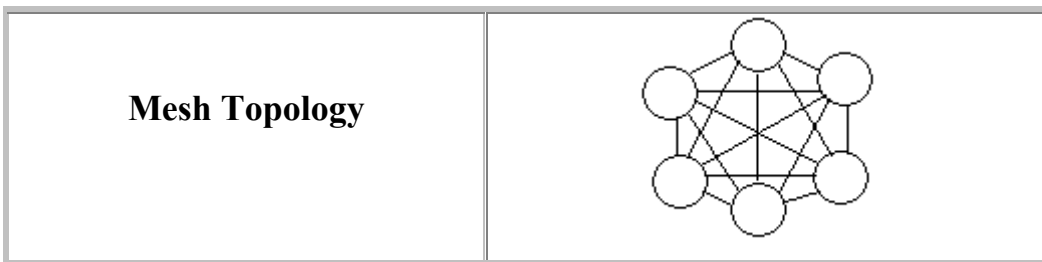
Tree topologies consist of bringing star topologies onto bus topologies. Only the hub connects to the tree as the root. The tree topology supports future expandability of networks better the bus or star topology by itself.

The bus is limited in the number of nodes due to the broadcast traffic it generates and the number of hub ports alone limits the star.



3.6 Mesh Topologies

Mesh topologies deal with the concept of routes. The messages are sent on routes that can take any of the several possible paths from source to destination. The nodes are connected with many redundant interconnections between network nodes. A true mesh topology has every node having a connection to every other node in the network.



Chapter 4

Conclusion

The question asked now is how do biomedical sensors and topologies coincide with one another? Wireless nodes are made to be mobile but biomedical sensor nodes are made to be stationary since they are implanted in the body. The placement of the sensors can be oppressed to create efficiencies that are unfeasible in mobile networks. There is no need for a self-organization protocol to allow individual sensors in the network to decide the closeness and number of neighboring sensors. Nor is there any requirement to expand a routing protocol among sensors to determine paths among sensors that need to converse. There is a need to find which topology might be most effective for the constraints set forth for a biomedical sensor network. Several constraints have been talked about in this paper. The next step is to take those constraints and tell which is the best way to arrange these sensors once they are implanted in the body

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