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ENERGY EFFICIENT DESIGN FOR MOBILE AD HOC SYSTEMS

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Abstract

A group of mobile nodes whose locations are chosen at random and in a dynamic way so that the connections between them can constantly change is called a mobile ad hoc network. In mobile ad-hoc network, all mobile nodes forms a network that does not have centralized manager. This new kind of network may be able to offer services in locations where they would not normally be able to. Multiple issues arise for this kind of networking when there is no stable infrastructure. The lithium-ion rechargeable batteries that power the majority of mobile Ad hoc network devices only last a few hours when used actively. Researchers attempted to optimize mobile device power usage in all areas in an effort to address this issue. Reduced power usage can occur at the device level, during transmission, or through the use of an improved power-aware routing protocol. A brief overview of the fundamentals of mobile ad hoc networks is provided in this study, along with a comparison of the various power-saving methods used in these networks.

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Introduction

A mobile ad hoc network, or MANET, is a network made up of mobile nodes (such as PDAs, iPads, laptops, smartphones, sensors, etc.) that communicate with each other wirelessly to transmit and receive packet data. MANETs are networks created without the need for centralized management. Nodes in this kind of network have the ability to act as hosts and routers, enabling them to run user applications and transmit packets with the help of other nodes. When communication is required but there is no infrastructure in place, ad hoc networks [5] are created. Ad hoc networks can be found in places like combat zones, disaster relief areas, and outdoor executive gatherings.

The lack of a centralized base station is what sets ad hoc networks apart from conventional wireless networks. When using a standard wireless network, nodes that want to talk to one another must first make contact with the base station that is closest to them. The base station nearest to its intended node receives the requests after that. The path that the base station has established is used to route each packet. Route maintenance, routing, and tracking are handled by the base stations. All these jobs are carried out by the nodes themselves in ad hoc networks, on top of their individual responsibilities. This shortens the batteries' lifespan by putting additional strain on them. Reducing the amount of power used to transmit a packet while avoiding nodes with low battery life can be achieved through the use of routing algorithms that improve power usage.

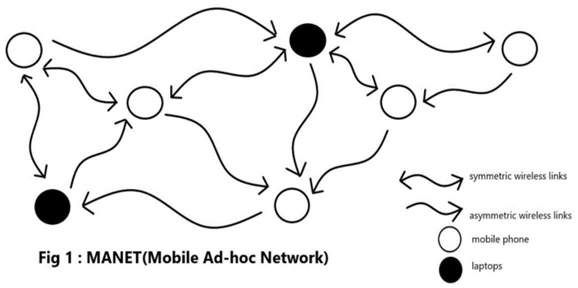

Fig 1 : MANET(Mobile Ad-hoc Network)

An example of an mobile ad hoc network is shown in Fig 1.

Symmetric Wireless Links: It is possible for Node 1 and Node 2 to interact

Asymmetric Wireless Links: Node 2 is unable to transfer data to Node 1, yet Node 1 can send data to Node 2

People sitting in airport lounges, taxis, military operations, and private area networks may have various mobility arrangements. Mobility characteristics include movement speed, direction, predictability, movement design, and feature consistency between nodes.

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I. MANET EVOLUTION

Three generations of ad-hoc networks.

First Generation

Back in 1972, there was the first generation. PRNET (Packet Radio Networks) was the name given to them at the time. The PRNET utilize CSMA (Carrier Sense Medium Access) and ALOHA[3] (Areal Locations of Hazardous Atmospheres), which merged medium access techniques with a variant of distance-vector routing. In order to test various networking features in a combat setting, PRNET was deployed.

Second Generation

When ad hoc network technologies were improved and included into the SURAN (Survivable Adaptive Radio Networks) program, the second generation of ad hoc networks appeared in the 1980s. In an un-infrastructured setting, this gave the mobile battlefield access to a packet-switched network. The radios' performance was enhanced by this effort, which made them more affordable, compact, and resistant to electronic assaults.

Third Generation

With the introduction of notebook computers and other practical communications devices in the 1990s, the idea of commercial ad hoc networks gave rise to the third generation of ad hoc networks. Simultaneously, other research conferences put out the concept of a collection of mobile nodes. Meanwhile, the research community had begun to investigate the feasibility of implementing ad-hoc networks in different application domains, and the IEEE 802.11 subcommittee introduced the phrase "Ad-hoc Networks".

II. MOBILE AD HOC NETWORK CHARACTERISTICS

Generally speaking, without the use of pre-existing network infrastructure or centralized management, a self-organizing network of mobile nodes connected by wireless transmissions establishes mobile ad hoc networks on quick basis. The wireless topology of the network can change rapidly and without indication because nodes are free to move and rearrange themselves whatever way they like. Such a network can function independently or it can be integrated into a bigger network. Due to their lack of need for established infrastructure, including base stations, mobile ad hoc networks are infrastructure-less networks..

The following characteristics of mobile ad hoc networks:

Infrastructure-Free and Independent

MANET operates independently of centralized management or any pre-existing infrastructure. Independent data generation, autonomous routing, and dispersed peer-to-peer operation are all performed by each node. The requirement to split network administration over several nodes makes fault detection and handling more challenging.

Distributed Operation

Control and administration of the network are divided among the terminals as there is no background network accessible for the central control of network operations. In a mobile ad hoc network, the nodes should cooperate with one another and each other when necessary to carry out certain tasks, such routing and security.

Multiple Hop Routing

All nodes in this type of network function as routers, forwarding each other's packets to allow mobile hosts to share information, even in the absence of a default router.

Adaptive Network Configuration

The network topology might alter quickly and unexpectedly due to the nodes portability, and the terminals connections will fluctuate over time. In addition to adjusting to node mobility patterns, the mobile ad hoc network should also adjust to movement and transmission circumstances. Within the network, mobile nodes repeatedly construct connectivity between each other as they move around and spontaneously create their own networks.

Variation in Link and Node Capabilities

Every node might be fitted with one or more radio interfaces that function across several frequency bands and have differing transmission/receiving capacities [1,2]. Links may become asymmetrical as a result of this variation in node radio capability. Additionally, the hardware and software configurations of individual mobile nodes may vary, leading to variations in processing power. It can be difficult to design network protocols and algorithms for this heterogeneous network as they must dynamically adjust to shifting circumstances (such as changes in power and channel conditions, traffic load and distribution, overload, etc.).

Network Scalability

The majority of widely used network management methods today were created to function on fixed or modest wireless networks. Numerous applications involving mobile ad hoc networks, such as tactical and sensor networks, sometimes include massive networks with tens of thousands of nodes. The effective implementation of these networks depends on their scalability. There are numerous problems that still need to be resolved in areas like addressing, routing, location management, configuration management, interoperability, security, high capacity wireless technologies, etc. when building a large network of nodes with constrained resources.

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Light-Weight Terminals

Ad hoc network nodes are portable gadgets with limited CPU processing power, smaller memory capacities, and minimal power storage. The algorithms and methods that carry out the processing and communication operations on such devices must be enhanced.

Energy Constrained Functioning

The restricted power supply of each mobile node's batteries results in a limited processing power capacity, which in turn restricts the services and applications that each node can support. Because each node in a mobile ad hoc network is simultaneously functioning as a router and an end system, forwarding packets from other nodes requires more energy, which makes the problem worse.

III. POWER SAVING TECHNIQUES

Each node might depend on portable, constrained power supplies because ad hoc networks does not rely on the existence of a stable infrastructure. Hence, in ad hoc networks, the concept of energy efficiency becomes crucial. The majority of current energy-saving strategies for ad hoc networks center on lowering the radio transceiver's power consumption. This is often accomplished at the MAC level and above by either choosing routes that need several short hops rather than a few longer hops, or by utilizing a transmitter with variable output power (and commensurate input power demand) and selectively sending the receiver into a sleep state [2].

Three strategies may be used in mobile ad hoc networks to lower power usage.

- ✓ Reducing Power Consumption at Mobile Device Level.
- ✓ Reducing Power Consumption by Managing a Packet's Transmission Level.
- ✓ Reducing Power Consumption by using optimized Power Routing Protocol.

A. Reducing Power Consumption at Mobile Device Level

Even when in sleep mode, mobile devices continue to utilize energy. For instance, mobile phones continuously drain power even when they are not in use since the trans-receiver is always listening for signals to send back to itself. Many efforts are presently being made to minimize the amount of power used by a mobile device in all of its aspects. We now provide a brief review of a few of these techniques.

Disk Scheduling

Efficient utilization of hardware, particularly disk drives with quick access times and disk bandwidth, is the responsibility of the operating system on a computer. The two main components of access time are rotational latency and seek time. The

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amount of time it takes for the disk arc to move its heads toward the cylinder holding the desired sector is known as the seek time. The extra time spent waiting for the disk to rotate the required sector toward the disk head is known as rotational latency. The total bytes transmitted divided by the total time from the start of the service request to the end of the last transfer is the value of disk bandwidth.

In mobile devices, spinning down a disk during idle time is one way to save energy [5]. The amount of time the disk is idle before spinning down is known as the spindown delay. A quantitative examination of the possible expenses and advantages of spinning down a disk during idle time is provided in [1]. Traces from the Sprite File system and DOS computers were used in the testing. The study's finding was that, in contrast to the majority of manufacturers' recommended spindown delays of 3-5 minutes, a spindown delay of two seconds produced the greatest power savings. Both the frequency and length of sleep were cited by the writers as evidence for this conclusion. Shorter delays, according to them, allow the disk to sleep for a longer period of time and conserve more energy.

Due to the time and energy required to spin up the disk, spinning down a disk after such little delays has the disadvantage of delaying user action. The spindown happens 8–15 times per hour, according to the traces the authors used. Comparing this to the power savings realized, the 16–30 seconds of user delay each hour seems acceptable.

CPU Scheduling

The foundation of multiprogrammed operating systems is CPU scheduling. The operating system can increase the machine's productivity by alternating the CPU across processes. A processor's power [5] consumption is closely correlated with the supply voltage, the clock frequency, and the switching capacitance of the various components. Every clock cycle, gates in CMOS CPUs exchange states, creating a short circuit between the ground and the power source. A higher frequency leads to a greater loss of power.

CV2F, where C is the total capacitance of the wires, V is the supply voltage, and F is the operating frequency, provides the amount of power required by the CPU. Several strategies have been presented to modify the idle time clock frequency. Its primary goal is to maintain a balance between periods of high CPU consumption and idle time. One useful method for achieving this is task or process scheduling.

There's almost always a deadline for completing a process. According to observations made in [4], idle time occurs during task scheduling even in the worst-case condition of the CPU. This idle time is called the slack time. By reducing the voltage and slowing down the processor, this idle time can be utilized to save energy. These methods are referred to as voltage

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scaling and voltage slowdown. By lowering the processor's operating voltage, we can minimize or completely prevent idle time by extending the processing time while still finishing the task earlier than processing time.

Memory Allocation

The most essential element of a mobile device is its data storage. Memory instructions are one of the biggest energy consumers in mobile devices. The memory's power consumption is particularly important and needs to be enhanced because many smaller gadgets lack an external storage unit. A DRAM that enables the various devices to be in different power states has been introduced by some memory devices, such as Direct Rambus DRAM (RDRAM). These gadgets are arranged as follows: Active, Standby, Nap, and Powerdown in decreasing order of power states and increasing order of access times.

Power consumption can also be decreased by using memory placement strategies for data and code. The remaining memory chips can be powered down if engaged pages with time-specific location are clustered altogether and put on the same chip's memory before moving on to the next. By using this method, the volume of power needed to read data from memory can be minimized. Utilizing the static, dynamic, and temporal locality placement principles can result in power savings of between 6% to 50%, according to the simulation results provided in [1].

B. Reducing power consumption by managing a Packet's Transmission Level

Selecting the transmit power for every packet at each node in a distributed manner is the power control issue in wireless ad hoc networks. Since selecting a power level has an fundamental effect on numerous aspects of the network's operation, such as:

i. The physical layer is affected by the transmit power level, which controls the quality of the signal received at the receiver.
ii. In terms of network layer routing, it establishes a transmission's range.
iii. It calculates the magnitude of interference it causes to the other receivers, causing overload in the transport layer.

Transmit power control, thus, is an outstanding instance of a cross-layer design problem, impacting the protocol stack at every level, from physical to transport, and altering several performance measures, such as the trinity of throughput, delay, and energy consumption. With some caution and a general strategy, cross-layer design should generally be executed while keeping longer-term architectural challenges in mind. This raises the question of where power control should be placed in the network architecture,

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the answer to which depends on understanding the problems at each layer.

❋ Design Principles for Power Control Protocol

Power management is crucial in wireless ad hoc networks for two reasons at minimum: it can affect battery life and the network's capacity for handling traffic.

The power control design principles are as follows.

1. In order to maximize the capacity of the network, it is necessary to lower the power used for transmission level.
2. At the MAC layer, average conflict is decreased by lowering the transmit power level.
3. The hardware's energy consumption pattern determines how power control affects overall energy usage.
4. A higher power level results in a smaller end-to-end delay under low traffic loads, while a lower power level results in a larger traffic load.
5. One may consider power control to be a network layer issue.

Kawadia and Kumar [6] have proposed numerous protocols that aim to accomplish several design objectives and multiple optimizations at the same time, based on the previously discussed design guidelines.

- ✓ By selecting a common power level throughput for the network, the COMPOW protocol [6] aims to address the demands of several layers while boosting network capacity.
- ✓ With the same objective of enhancing network capacity, the CLUSTERPOW protocol [6] simplifies this restriction and offers a combined solution to the power control, clustering, and routing problems.
- ✓ Depending on the wireless technology, the MINPOW protocol achieves a globally optimal energy consumption solution for awake nodes, but it may or may not boost network capacity.

C. Reducing Power Consumption by using optimized Power Routing Protocol

Finding a path from a source to a destination node is known as routing, and it can be done in one of two ways: either by computing all routes in advance and sorting them previously or by computing them only when necessary.

A routing protocol describes the way in which routers interact with one another in order to share data that enables them to choose the best route between any two network nodes. Usually, a router only knows initial information about its immediate neighbours. To enable routers to be informed about the overall network topology, a routing protocol transmits this data.

Since each host in a wireless ad hoc network serves as both a router and a packet sender, ad hoc mobile networks cannot be connected to wired networks using the traditional routing protocols. Based on the

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following three factors, ad hoc routing protocols can be categorized: based on the routing path's creation, its logical structure, and its techniques for obtaining routing information.

- Based on the logical organization through which the protocol "Describes" the network.

It is possible to categorize routing protocols into two groups: "Uniform" and "Non Uniform" based on their logical organization.

In a uniform protocol, every node sends and replies to routing control messages in the same way, with no node taking on a unique role in the routing scheme. There is no fixed hierarchical structure on the network. While maintaining high-level structure can be eliminated by such a protocol, scalability could become a problem in larger networks.

Non-uniform protocols try to lower the number of nodes involved in a route computation in an effort to reduce routing complexity. In contrast, it can enable the adoption of algorithms with higher computational or communication complexity than what is achievable in the entire ad hoc network. Such an approach can increase scalability and decrease communication overhead. Higher-level topology data can also help with QoS support and load balancing.

- **Based on the way routing information is obtained**

Routing protocols can be categorized as reactive (on-demand), proactive (table-driven), or hybrid depending on the type of routing information.

→ Proactive (Table-Driven)

Every node in a network that uses table-driven routing protocols keeps track of one or more tables providing routing details for all other nodes. To keep a consistent and current representation of the network, each nodes must update these tables. In order to keep uninterrupted and current routing data about the entire network, nodes transmitting update messages throughout it when the topology of the network changes. By distributing routing tables across the network on a regular basis, this kind of protocol keeps up-to-date listings of destinations and their routes. WRP (Wireless Routing Protocol), DSDV (Destination-Sequenced Distance-Vector), and other protocols are examples of proactive protocols.

- **Reactive (or On-Demand)**

Source-initiated on-demand routing is an alternative technique to table-driven routing. Reactive routing of this kind only generates routes when the source node requests them. A network's route discovery process proceeds by a node looking for a route to a destined location. Once a route has been determined or every possible combination of

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routes has been considered, this process is accomplished. Route maintenance procedures evaluate the route until they decide that the destination is no longer desired or that there is no way to reach there from any route that starts at the source.

Reactive protocols minimize signaling traffic but extending delivery times by requiring a method to determine the most suitable route only if packets are to be exchanged.

AODV (ad hoc on- demand distance Vector), DSR (dynamic source routing) and TORA(temporally ordered routing algorithm) are few examples of Reactive protocols.

→ **Hybrid**

Proactive and reactive routing benefits are merged in this kind of protocols. First, some proactively prospected routes are established, and then reactive flooding is used to meet the demand from additional activated nodes.ZRP (Zone Routing Protocol) and HRPLS (Hybrid Routing Protocol for Large Scale Mobile Ad Hoc Networks with Mobile Backbones) are a couple of instances of reactive protocols.

❋ **Depending on the routing path's creation method**

The routing path is defined as the path a packet will take from its source to its destination. The two types of protocols that can be identified on the basis of the routing path are Source Routing and Non Source Routing. The sending node in the first one recognizes the entire path to the destination and records it straight into the packet; as a result, intermediate nodes only re-transmit packets to those that are addressed by the path that was previously established. Instead, in the latter case, every node must be able to improve routing decisions because the only routing information present in data packets is that reflected by the effective neighbour node to whom communication needs to be routed.

IV. CONCLUSION

We have reviewed the properties of mobile ad hoc networks and examined the challenge of power management in these networks in this paper. We have examined the many power-saving strategies now in use. In contrast to power saving at the device or transmission level, routing protocol power saving is considerably less challenging. All these methods help reduce the energy consumption of mobile devices, but when we combine them, the energy savings are massive and the network's lifespan is enhanced.

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