

Physical Layer and Transceiver Design Considerations:

The physical layer is mostly concerned with modulation and demodulation of digital data; this task is carried out by so-called transceivers. In sensor networks, the challenge is to find modulation schemes and transceiver architectures that are simple, low cost but still robust enough to provide the desired service.

Some of the most crucial points influencing phy design in wireless sensor networks are:

- †. Low power consumption
- †. Small transmit power and thus a small transmission range.
- *. Low duty cycle. Most hardware should be switched off or operate in a lower-power standby mode most of the time.
- *. Needs low data rates in the order of tens to hundreds Kibits per second.
- *. Easy implementation and low costs
- †. Low degree of mobility

Energy usage profile:

The choice of small transmit power leads to an energy consumption profile different from other wireless devices. Some

of the differences are described below.

First, the radiated energy is small, typically on the order of 0dB (corresponding to 1mW). On the other hand, the overall transceiver consumes much more energy than is actually radiated. The transceiver which works at the frequencies more than 1GHz will consume 10 to 100mW of power for radiating 1mW. Similar numbers are given for 2.4GHz CMOS transceiver, radiated power is 0dB = 1mW and uses actually 32mW. So, Many practical transmitter designs have efficiencies below 10% at low radiated power.

A second key observation is that for small transmit powers the transmit and receive modes consume more or less the same power. In fact, the receiver needs more power than that of the transmitter. To reduce the average power consumption, keeping the transceiver in idle mode; depending upon the architecture the power consumption of the idle mode might either be lower or same to that of required for reception. For this reason, the transceiver must be switched to sleep mode rather than idle mode.

However, there is the problem of the startup energy / startup time, which a transceiver has to spend upon coming up from sleep mode. During this startup time, no transmission or reception of data is possible. Example: MAMP-1 transceiver needs startup time of 466 μ s and power dissipation of 15mW. Therefore, going into sleep mode is unfavorable when the next wakeup comes fast.

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The third difference is the relative cost required for³³ Communication and Computation in sensor node. For Comparing the costs of Computation with Communication, the communication is found to be costlier than the Computation; because for the WSN nodes, 1500 - 2700 instructions can be executed per transmitted bit so the range is upto 2900:1. So that computation is cheaper than Communication.

Choice of modulation Scheme:

A crucial point is the choice of modulation scheme.

Several factors have to be balanced here:

- *. Desirable data rate and symbol rate
- *. Implementation Complexity
- *. The relationship between the radiated power and target BER.
- *. Characteristics of expected channel.

To maximize the time a transceiver can spend in sleep mode, the transmit times should be minimized. An increase in the data rate of transceiver/modulation will decrease the transmit time and energy consumption for a given amount of data. The energy consumption of a modulation scheme majorly depends on the symbol rate than on the data rate. It has also been found that for the 1Amps-1 nodes the power consumption is insensitive to the data rate.

Obviously, the desire for high data rates at low symbol rates

calls for m-ary modulation schemes. However there are trade-offs:

- Most of the m-ary modulation schemes are used for increasing m an increased E_b/N_0 ratio and consequently an increased radiated power to achieve the same target BER. and to attain the targeted bandwidth efficiency ratio.

- It is expected that in many WSN application most packets will be short, on the order of tens to hundreds of bits. For such packets, the startup time easily dominates overall energy consumption, rendering any efforts in reducing the transmission time by choosing m-ary modulation schemes irrelevant.

Dynamic modulation scaling:

Even if it is possible to determine the optimal scheme to achieve BER, range, packet size and so on, such an optimum is only valid for short time; as soon as one of the constraints changes, the optimum can change, too. In addition, other constraints like delay or high throughput will surely lead to change in the choice of optimum scheme. or to choose higher modulation schemes.

Therefore, it is important to consider methods to adapt the modulation scheme to the current situation, such approach is called as dynamic modulation scale.

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For the case of m -ary QAM particularly. A target BER is 10^{-5} . A model which makes the use of symbol rate B and number of levels for every symbol m as parameters have been developed. It represents the required energy and obtained delay for each bit. It assumes that the higher modulation levels require the highest radiated energy in order to compensate for higher bit error rates.

Any additional required for startup are not considered. The symbol rate B and number of levels m are increased by decreasing the bit delay. The energy and delay for each bit are reduced to increase the symbol rate for specific parameters.

By making use of modulation scaling, a packet can be appended to the delay constraint. This delay constraint is later on used to derive minimum data rate directly. A minimum value of m must be chosen as per the requirement of data rate. This is because the symbol rate will be fixed at a point. It also reduces the energy needed for each bit. These delay constraints can be assigned implicitly or explicitly.

Antenna Consideration:

The desired small form of the overall sensor nodes restricts the size and the number of Antennas. If the antenna is much smaller than the carrier's wavelength, it is hard to achieve good antenna efficiency and spend more transmit energy.

to obtain the same radiated energy.

Secondly, with small sensor node cases, it will be hard to place two antennas with suitable distance to achieve receive diversity.

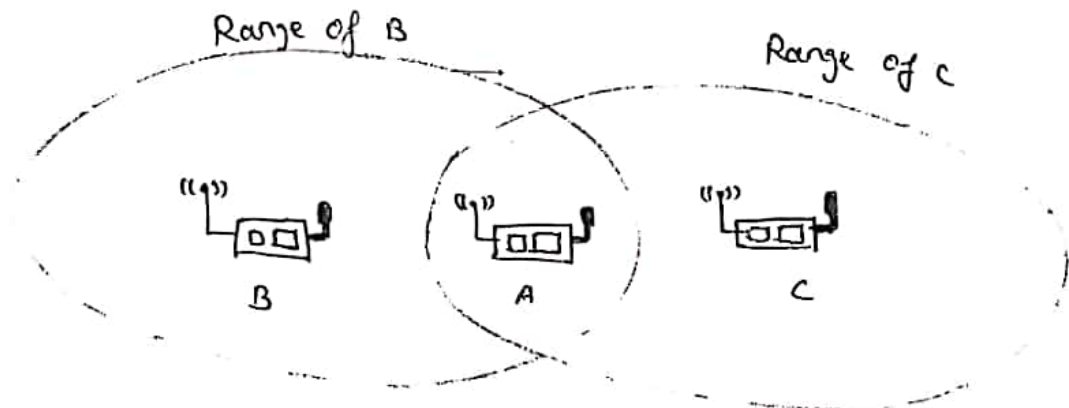
In addition, radio waves which are emitted from the antennas which are very near to the ground in certain applications will face a problem such as path-loss coefficients which are larger than that of the common value $\alpha = 2$ in order to allow communication in free space.

Antennas need not be extended from the casing of a node for avoiding any occurrence of damage. Such restrictions will limit the quality that can be achieved and also the relative characteristics of antenna for wireless sensor nodes.

Nodes randomly scattered on the ground, for example, deployed from an aircraft, will land in random orientations, with the antennas facing the ground or being otherwise obstructed. This can lead to nonisotropic propagation of the radio wave, with considerable differences in the strength of the emitted signal in different directions. This effect can also be caused by the design of an antenna. Antenna design itself is considered as an issue.

Hidden node and exposed node problem:

Hidden node problem:



B and C are hidden from each other w.r.t A.

Let consider we have three sensor nodes A, B, C respectively. Each node has its own transmission Range. The nodes are transmits the data isotropically. The left oval represents the B-node transmission range and every node in this range can hear any data transmitted by node B. The right oval represents the C-node transmission range and every node in this range can hear any signal / data transmitted by node C. Likewise node B is outside the range of node C. Node A is in the area covered by both B and C; it can hear any signal transmitted by B or C.

Assume that node B is sending data to station A. In the middle of transmission, node C also has to send to node A. However node C is out of B's range and transmission from B cannot reach C. Therefore C thinks the

channel is free and sends the data to A, which results in collision at A because this station is receiving data from both B and C. In this case, we can say that station B and C are hidden from each other with respect to A. Hidden stations can reduce the capacity of the network because of possibility of collision.

The solution to the hidden node problem is the use of handshake frames (CTS + RTS).

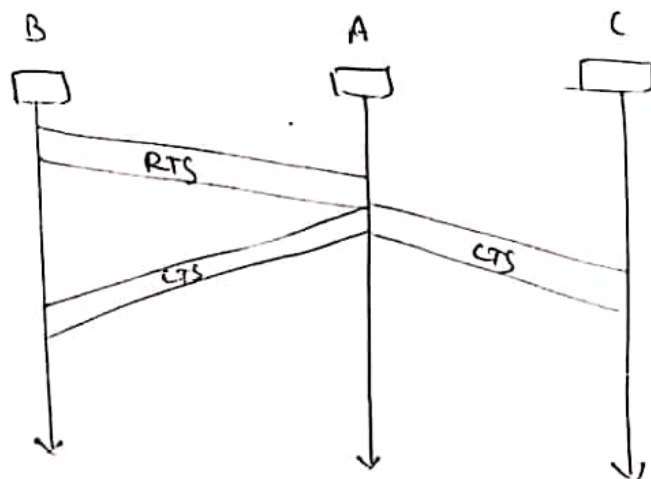
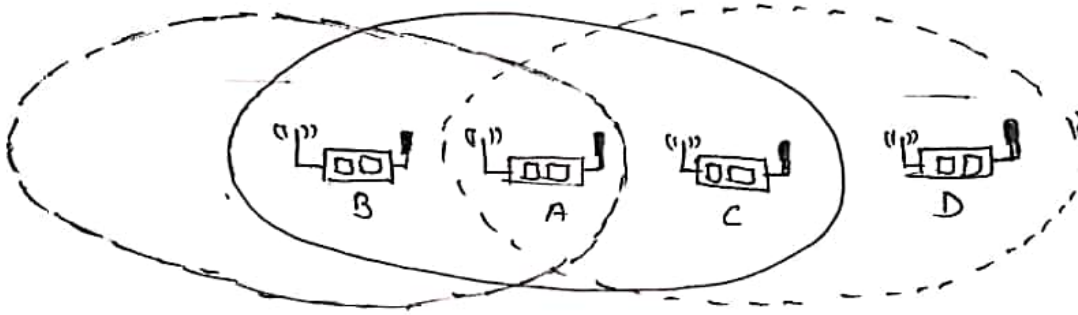


Figure shows that the ^{Request} ~~Ready~~ to send message from B reaches A, but not C. However, because both B & C are within the range of A, the clear to send (CTS) message, which contains the duration of data transmission from B to A reaches C. So, the C knows that some hidden node is using the channel and refrains from transmitting until that duration is over.

Exposed node problem:

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Range of A



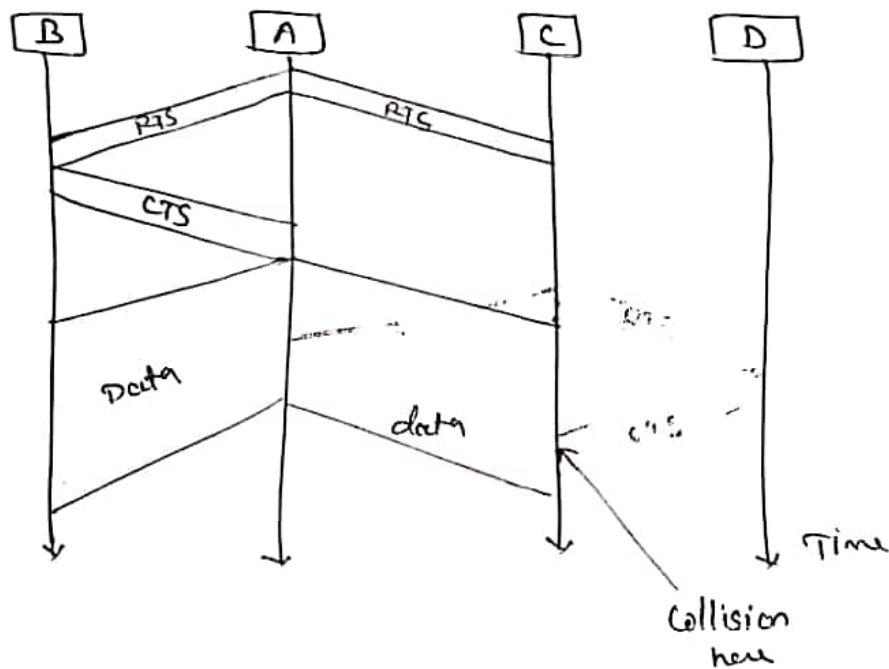
C is exposed to transmission from A to B.

Now consider a situation that is the inverse of the previous one: the exposed node problem. In this problem, a node refrains from using a channel when it is free or Available.

Node A is transmitting to node B. The station C has some data to send to station D, which can be sent without interfering with the transmission from A to B. However the node is exposed to transmission from node A; the node C hears what A is sending and thus refrains from sending. In other words node C wasted the capacity of the channel and C is too conservative.

The handshaking messages RTS and CTS cannot help in this case. Station C hears the RTS from A, but does not hear the CTS from B. The node C after hearing the RTS from A, can wait for a time so that the CTS from B reaches A; it then sends an RTS to D to show that it needs to send the data to D. Both

D and A may hear this RTS, but station A is in the sending state, not the receiving state. If station A has started sending its data, node C cannot hear the CTS from node D. because of collision; it cannot send its data to D. It remains exposed until A finished its data. which is shown in figure.



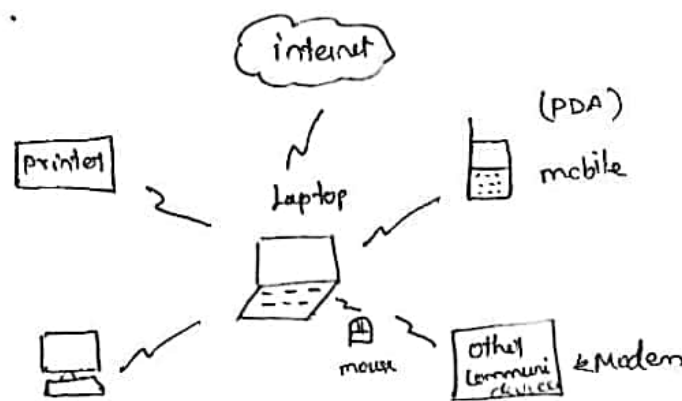
Personal Area Networks: (PAN)

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PAN is smallest network which is very personal to a user. It is a network used for data transmission among devices such as Computer, telephones, PERSONAL digital Assistants (PDA) and other communicating devices.

These Networks are designed for inexpensive connecting low power devices located within 10m to 100m of each other, in which connections are wireless.

The technology used in WPAN are Bluetooth and Infra-red.



It helps to communicate and transmit data among multiple hardware devices using one computer.

Fig: Wireless Personal Area Network

The PAN can be used to connect Laptop, PDAs, portable printer, desktop computer. PAN may include wireless computer keyboard and mouse, Bluetooth enabled headphones, wireless sensing node and TV remote.

It offers GPRS/UTMS services on mobile phone with which the user can connect to internet or to incorporate

IP network. In wireless PAN the devices need to be in the radio vicinity of each other in order to create a communication medium among them. The bluetooth protocols allow them to form a network when they are in the vicinity of each other.

Another important feature is the ability of each device to lockout other device selectively, preventing needless interference or unauthorized access to medium.

The proposed operating frequency is around 2.44GHz.

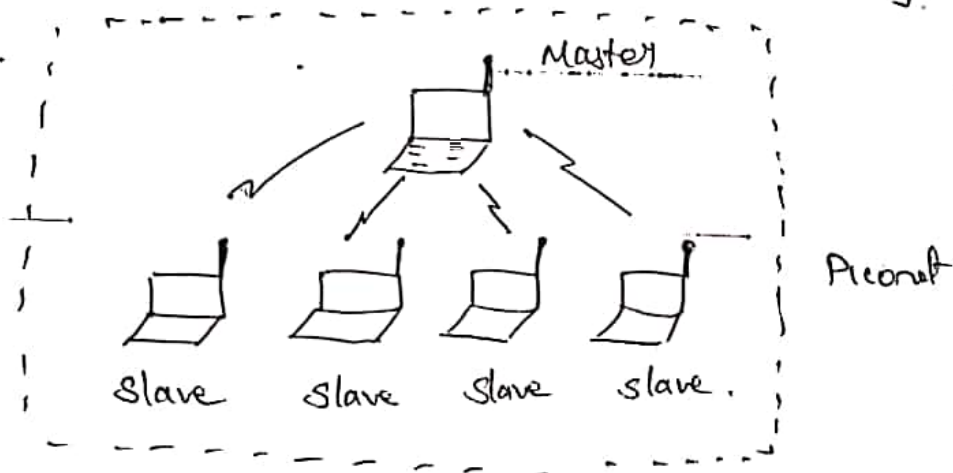
Topology of PAN: 'Point to point' link and 'star topology'

In PAN network, commonly used topology is "star topology". In star topology, each device has dedicated point-to-point link only to a central controller, usually called Hub. The link used here is wireless link. The enabling Technology used in PAN network is Bluetooth. It defines two type of networks : Piconet and Scatternet.

Piconet:

A Bluetooth network is called a piconet or small net. A piconet can have up to eight stations, one of which is called the master; the rest are called slaves. All the slave station synchronize their clocks and hopping sequence with the master slave. Note that a piconet can have only one master. The communication between the master and

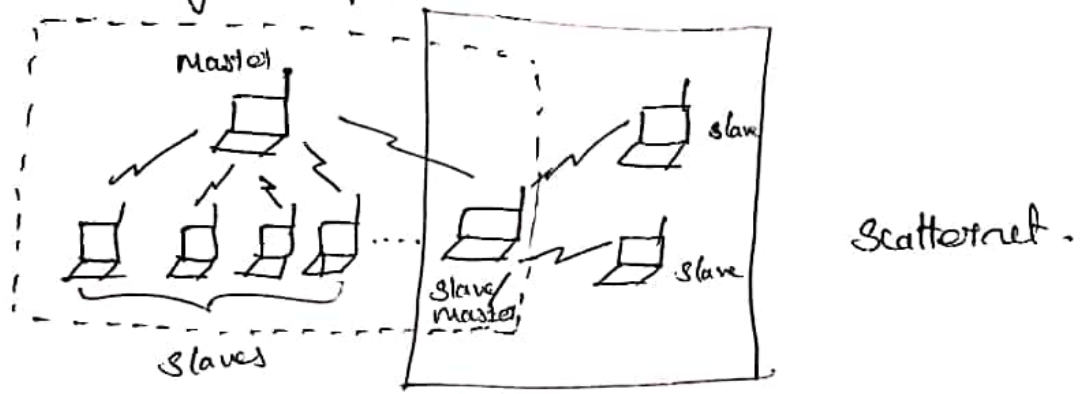
Slaves can be one-to-one or one to many.



Although a piconet can have a maximum of seven slaves, an additional eight slaves can be in the parked state. A slave in a parked state is synchronized with the master, but cannot take part in communication until it is moved from the parked state.

Scatternet:

Piconets can be combined to form what is called scatternet. A slave station in one piconet can become the master in another piconet. This station can receive message from the master in the first piconet (as a slave) and, acting as a master, deliver it to slaves in the second piconet. A station can be a member of two piconets.



Note: IEEE 802.15 standard defines a WPAN operable in an area the size of a room or a hall

Topology of MANET:

A Mobile ad-hoc Network is a continuously self-configuring, infrastructure-less network of mobile devices connected without wires. Each device in MANET is free to move independently in any direction and will therefore change its link to other devices frequently. Thus, the network topology may change randomly and at unpredictable times.

A highly dynamic topology is a distinguishing feature and challenge of mobile ad-hoc Network. Links between nodes are created and broken, as the nodes move within the network. This node mobility not only affects the source and/or destination as in a conventional wireless network, but also intermediate nodes, due to the network's multihop nature.

In a MANET, mobile nodes act not only as end systems, but also as routing devices. The topology of the network is dependent on the relative locations and connections of nodes within the network. This results in a topology that is extremely dynamic.

Because of the following reasons, several problems may arise during the design of mobile ad-hoc networks as follows

- *. wireless medium which possess the sharing nature
- *. limited wireless connectivity range.

* mobility of nodes

* Energy constraints.

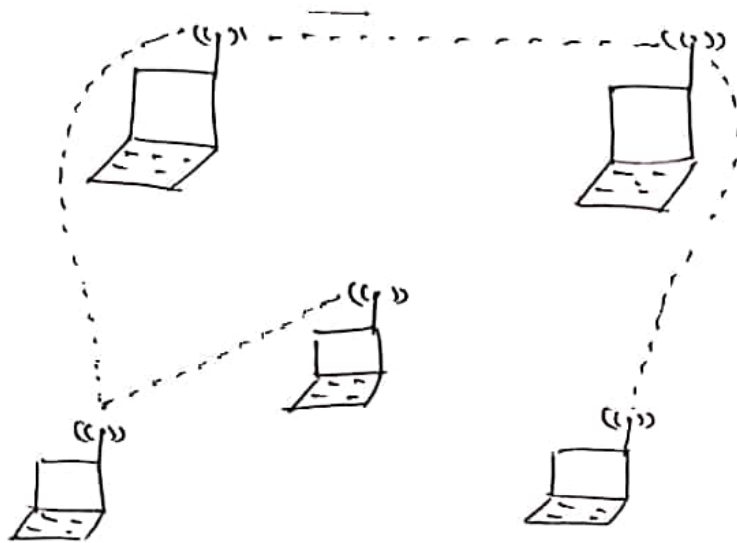


Fig: mobile Ad-hoc n/w

Mobile ad hoc network is decentralized wherein the mobile node has the routing functionality i.e., the nodes themselves perform all the network tasks like topology discovery and message delivery. The applications used for MANETs are different ranging from small static network to large dynamic network. The design of network protocols become complicated for these kind of networks. MANETs need efficient distributed algorithms so that, scheduling and routing network organizations can be determined.

In the case of static networks, the shortest path from source to destination node is considered as an optimal route. But this mechanism is hardly extended in MANETs. The following issues that arise in MANETs.

1. Wireless Link Nature
2. Propagation path Loss
3. Multiuse interference
4. Power consumption
5. Fading
6. Frequent change in topology.

MANET perform the network functionality even in the absence of fixed infrastructure. When there exist no access point in the ad-hoc network, then the network facilities are provided by a popular and advance IEEE 802.11 Wi-Fi protocol. But in this situation, limited nodes are available for transmitting and receiving the information and no routing is done across the network. Mobile ad-hoc network operate independently or may be connected to large network called Internet. The application of MANET include a military operation or a disaster recovery.

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WANET Topology: (Wireless Ad-hoc Network)

A WANET connects a number of mobile devices that communicate through wireless medium. They are treated as node in the network and they use radio transmitter and receiver to communicate with other devices. The communication links depends upon the wireless technologies and the structure of topology of the network is built through dynamic network.

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Connectivity. It is not predefined. The common subtypes of these networks are mobile ad-hoc networks, wireless sensor networks and wireless mesh network.

WANET poses a unique feature like self organization so it not require any base station for communication purpose. All the nodes present in the networks plays the role of packet creator and router i.e., they create the packets as well as route them to their specified destination. It can extend its access offered in fixed network services by connecting to the gateways.

Hence, WANETs are multihop wireless network inherently when compared with other networks.

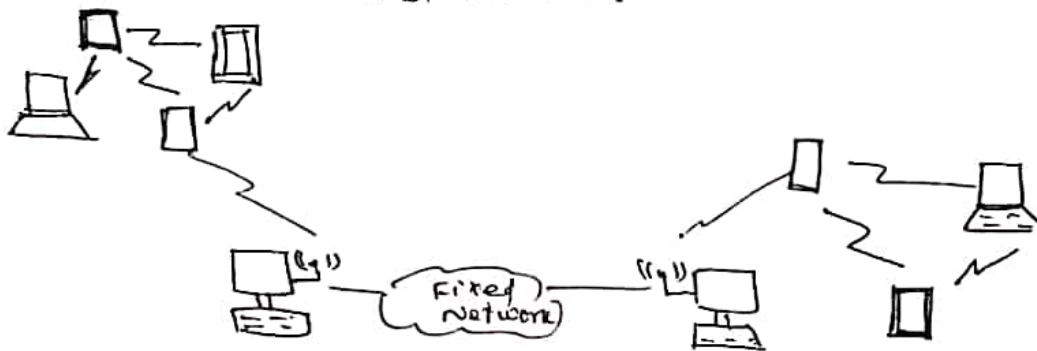


Fig: Fixed Network Multihop WANET

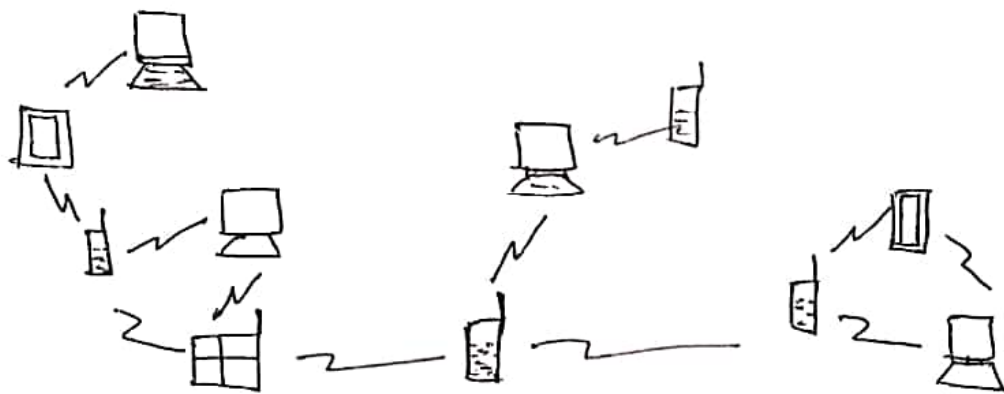


Fig: Self organized Multihop WANET

