Ch-1

Date : _____

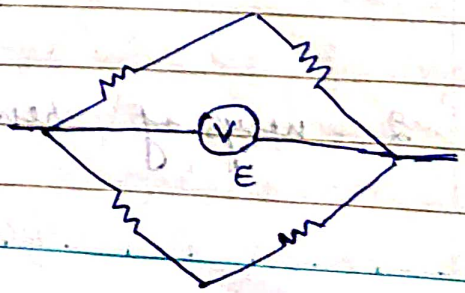
Intro and evolution

- Network : is a collection of devices / sources to perform a certain task.
- Sensor : is a device that converts one form of energy into a suitable other form.
  - electrical nature of signal.
  - can sense physical or physiological parameters.
- eg. (i) (Psi) → [pressure sensor] → (mA)

(ii) (Temp) → [Thermo Couple] → (μA)

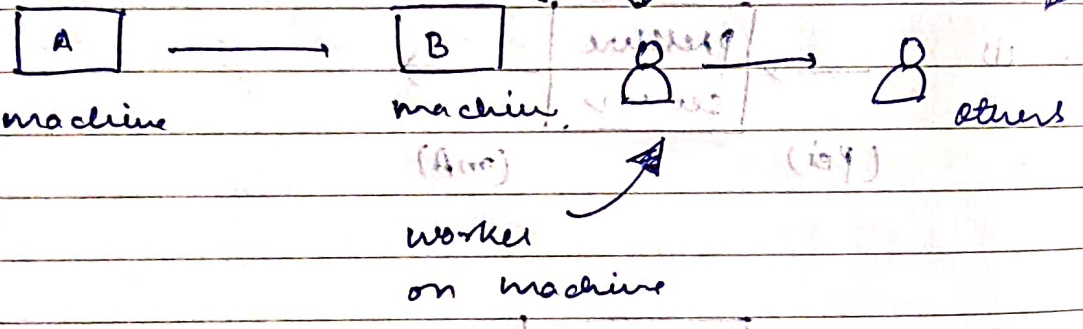
(iii) (Temp) → [Resistance temp. deflection] → change in Resistor. (ΔR) → [Deflection Bridge] → (volt)

if a sensor doesn't give an electrical signal then deflection bridge is used.



Date :

- req. of sensor changes with applications
- Information from physical world is meaningful only if it is be shared / interacted with humans.
- 3 steps
- ~~ways~~ of communication :
  - machine to machine interaction
  - " human "
  - human " machine



embedded sys. which is controlled by humans.

done in order

- Another info. sharing way is to directly share with humans. (done nowadays)
- communication : is process of transmitting info from one place to another place.
- base band : communicates over shorter dist.
  pass " : " longer "
- 2 ways of remote comm. → wired, wireless.

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- biggest disadvantage of wired : not cost effective, cost ↑ as nodes / devices ↑.

another big issue : doesn't allow devices to be mobilized.

Hence, that's why we use and prefer wireless comm.

A collection of tiny, diff. sensor nodes in order to collect real world info. via wireless comm. is a wireless sensor networks. and distributed

- sensor node : ~~collectio~~ combination of sensing device, processing device & controlling and comm. of signal in a single setup.

(there is a difference b/w sensor & sensor nodes)

- The motivation for WSN came from embedded sys. controlled
  - info
  - ~~for~~ control ← human
  - actuator

(or embedded ~~sys~~ control sys.)

~~if there is a~~

- Actuators are those that provide the final control signal which may be a human or a device-based control. If a device is capable of proces the physical world info along with control of the info, i.e. computat- exerts ing in the device ~~for~~ control action, that sys. is called embedded sys. / embedded control sys.

Date :

~~Evolution~~

- Ambient intelligence : different devices are able to process info and control the action with another devices, in an un-obstructed manner.
- Along with info sharing & control, if comm. is carried out, then the concept of WSN has evolved.

Performance of WSN (Performance Matrix)

(1) Energy efficiency

- since power supply is not possible always, the battery of should be energy efficient.
- eg - sensors in natural habitat like marine life, can't have a regular power supply & hence need batteries.

(2) No of sensor nodes

- it is a imp. factors.
- no ↑ ⇒ complexity ↑ ⇒ but can't say about cost or accuracy. (depends on application area)

Date :

- eg. 20 sensors may be less costly & less accurate than 5 sensors

(3) Accuracy.

- Many scenarios like intrusion detection system, req. high accuracy.
- Varies as application changes.

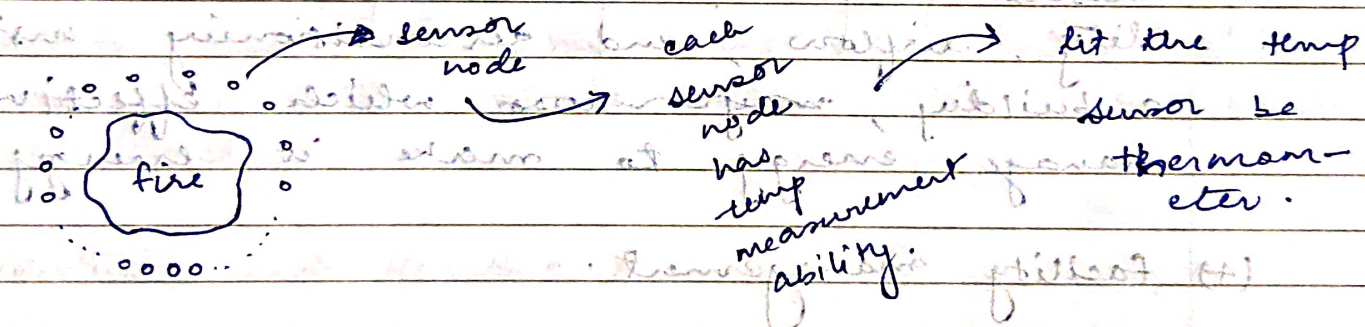
(4) Cost.

- It needs to be cost effective and depends on the nature of WSN application.

Applications of WSN.

(1) Disaster Relief Operation

- eg. forest fire is where we can use WSN to monitor it.



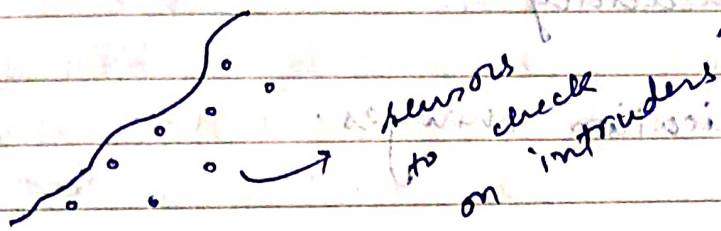
- In forest fire / wildfire there is a chance of a spreading fire which can be severe, thus temp. sensor having thermometer are used to check and monitor if the temp. exceeds the threshold limit. If this happens, the temp map is detected.

* like [illegible] for marine monitoring etc.

Date :

- In wildfire, CO_2 monitor sensor wont be suitable since it is difficult to accurately measure CO_2 level in a forest - compared to temp. ~~trust~~

- Another eg. military applications:



these sensor -
cost : low
lifetime : low
no : large

(2) Environmental monitoring and biodiversity.

- eg. building a wildfarms. For building them, we need to check if erosion is happening or not. If not, then we can build. *

(3) Intelligent Buildings

- Sensors that monitor and maintain the humidity, airflow, and airconditioning inside a building, ~~may~~ which effectively manage energy to make it energy efficient

(4) facility management.

- In many companies, employees can use "key less operation and entry". Also they can use intruder surveillance and ~~defe~~ detection in order to avoid ~~the~~ non employees in specific areas. Here lifetime is required.

Date :

(5) Machine surveillance & preventive maintainance

When machines work, they cause vibrations. If this exceeds the limit, human being cant go and check manually. Thus, sensor are used.

- There are certain areas where vibration of machine is too high making it dangerous to operate. Hence, sensor are used to maintain this check and take preventive measure if required.

(6) Precise agriculture

- sensors can be used in pest control, and to maintain soil humidity / moisture, and irrigation level.
- In agriculture, for smart irrigation and fertilization, soil moisture and humidity sensor are used. To control insects, WSN are used as well.

(7) Medicine and Healthcare

- Attaching sensors, device to patients is good but not advisable. So nowadays, monitoring health vital without attaching any devices is being research & used now.

(8) Logistics

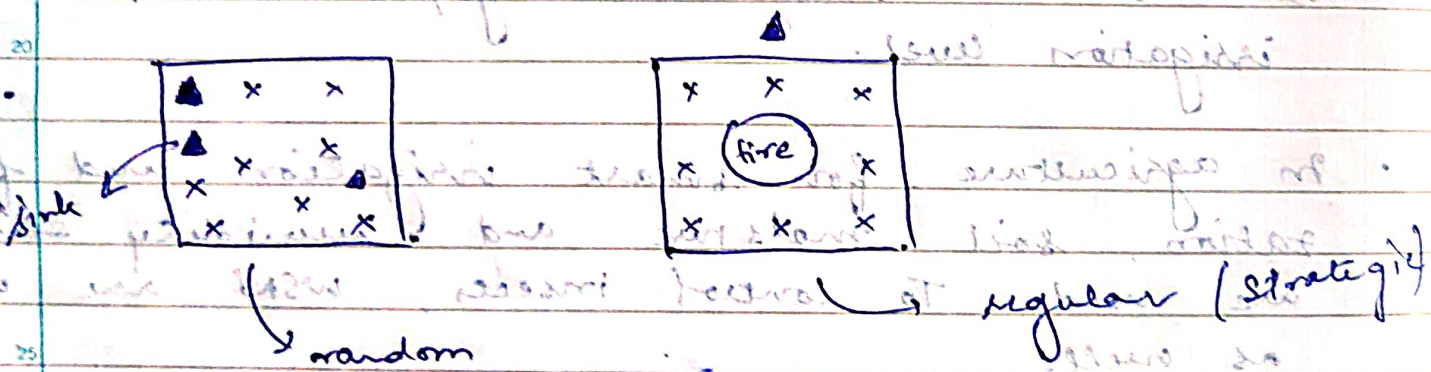
- On airports, unique RFID tags to each bag. This is a device based. The bags can be then returned to the owners later on.

(9) Telematics

- Info about the condn of traffic is forwarded to the driver.

Source vs Sink

- The no. of sink is quite less than the no. of sources.
- A sink may / may not be always present in the network.



Each sensor has the ability of finding its location.

- Sink node is also called as fusion centre or central processing unit.

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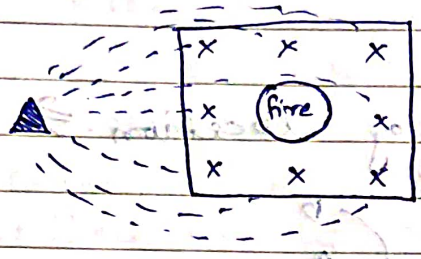
- sink has to be a powerful computing and accurate system since it has to process huge amount of info.

- The data transmission from source to sink, is carried by centralized architecture as all source info is going to a central processing unit.



centralized framework.

central framework is accurate than decentralized but is nowadays less preferred due to the possibility of sensor node / link failure. Moreover the sink needed in centralized is costly.

Type of application

- It depends on interaction b/w source & sink. They are of diff types —

- event detection
- periodic measurement
- fine approximation & age detection
- tracking
- maintenance req. options
- options for energy supply

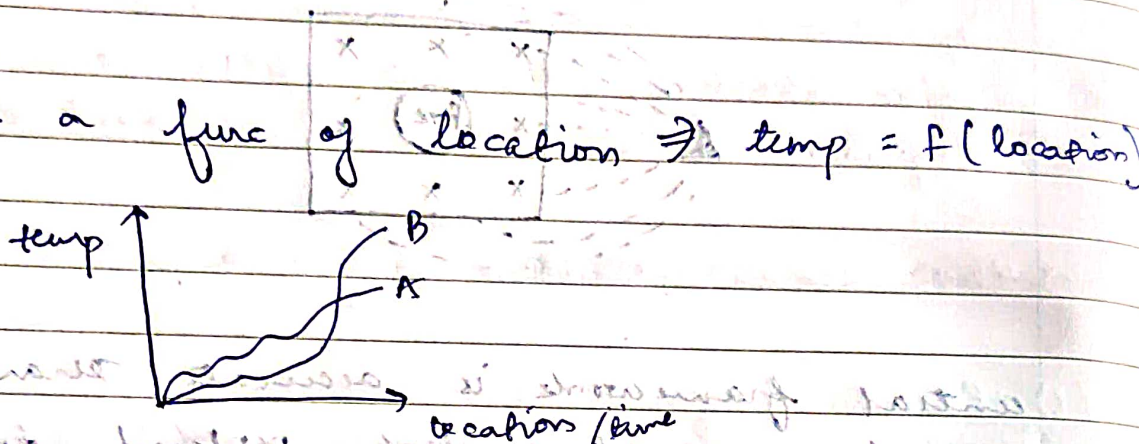
Date :

- event detection

single → e.g. temp of a node

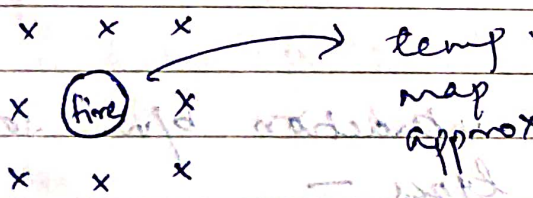
composite → e.g. temp gradient

- temp is a func of location ⇒ temp = f(location)



- func approx is needed

- isothermal points of wildfire



func. approx is where the variation of a particular func. is considered. eg. finding isothermal pts in wildfire, boundary & edge pt info is given to sink node. func. approx is always carried at sink node.

Date :

- In Tracking applications, the source is mobile.
eg: Intrusion detection systems; logistics.
Movement, speed and dirⁿ of the people / object to be tracked is imp.

Here, node deployment is also imp as the src are mobile and after a certain time, the movement is high. Thus sensor nodes are mobile as well.

for tracking scenario, either strategic or random node deployment is done. In random deployment, sensor nodes are mobile which allow better sensing ability

- maintenance requirement / option

not req. — if lifetime req is not there or low

req. — lifetime req is needed or high

- Options for energy supply
  - external power supply
  - internal "

Depending on the application, in some WSN, power supply through wired application. But

Date :

in others, inbuilt / internal power supply is needed. The energy supply depends on the size of the node.

Challenges in WSN

- ~~Quality of service (QoS)~~

(1) Quality of Service (QoS)

- delay - indicates the amt of time req by the actuator to perform control action.
- packet / data delivery ratio

- Quality ↑ ⟹ delivery ratio ↑ & delay ↓.

(2) fault tolerance

- major faults : - node failures
  - interaction of diff signals b/w sensor nodes

- one of a major / basic reasons of node failure is the power supply.

: To counter these faults, WSN use redundant ~~nodes~~ sensor nodes, to fill-in for failed nodes.

Date :

(3) life time (energy efficient)

- sufficient energy is req for inc. life time
- As for most sensor nodes, external power supply isn't possible & the inbuilt power supply is batteries — which get discharged after certain time. Thus recharging batteries can be done via external solar cell.
- If load distribution is even ⇒ lifetime T.
- lifetime : the time when a single node of a network gets failed.
  In certain cases, it's the time when 50% of sensor nodes fail.

(4) Scalability

- low / small scale problems are not preferred due to less datasets ⇒ less node accuracy.
- Nowadays real world prob uses large datasets. These large scale prob can be solved via WSN. Thus WSN architecture & protocols also need to be scalable.
  - architecture → arranging nodes
  - protocols → procedure of comm.

(5) Wide range of densities

- density : no. of sensor nodes.

- In diff. application, no. of nodes is diff. Thus density of nodes varies wrt time & space. Sometime it also changes due to node failure & movement.

(6) Programmability

- It is essential, to handle change of task which means changing operation of sensors to deal with new & diff. task.

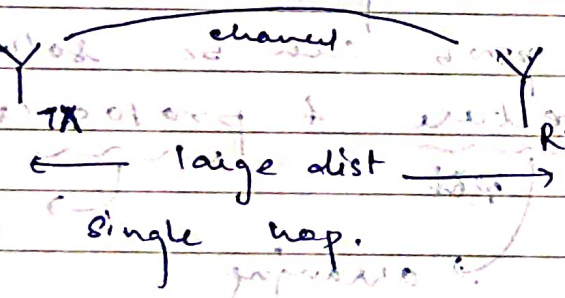
(7) Maintainability

- WSN must be able to maintain its ~~work~~ results.

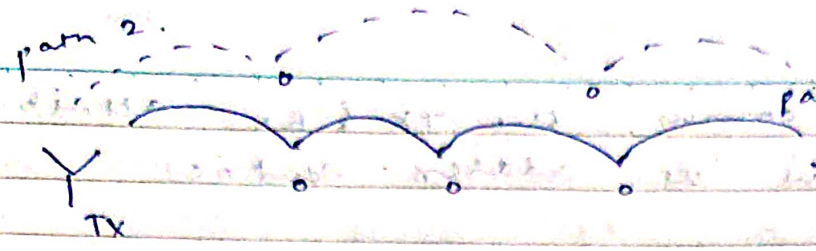
Dealing with challenges

- To deal with challenges, certain mech. is required.

(1) Multi-hop wireless comm.



- signal can be fuzzy, noisy ~~delay~~
- huge transmitter power & complex transmitter circuit
- high cost.



Date :

~~energy efficient~~
- less power req.
~~↓ delay~~
- ↓ noise.
- ↓ complex circuit

⟵ large dist ⟶

multi-hop.

- if one path fails, other alternative paths are used.

(2) Energy efficient operations

- design of energy efficient nodes deals with inefficient energy constraints of sensor nodes.

(3) Auto configuration

- In WSN, sensor nodes can exactly determine their location wrt to others. The network can also detect failure of nodes.

(4) Collaboration & in-network processing.

- This leads to energy efficiency.

- collaboration is imp. since individual sensor data transmission req. transmission power. However in in-network processing, sensor data are combined & then sent to the sink node.

(5) Data centric.

Date :

- In normal comm, the Tx & Rx attributes are imp. Thus it is address centric.

But in WSN, comm: is data centric. It doesn't matter from where / which sensor, info is coming but it focuses on 'what' data is coming — whether it is meaningful or not.

(6) locality.

- it ensures scalability & distributed / decentralized zone
- If sensors don't work, they can ask their neighbours or other in their sensing zone about the info. This combined info is imp.
- Neighbours of sensor are those sensor node can come in the sensing zone / raige of that sensor.

Date :

Ch-2

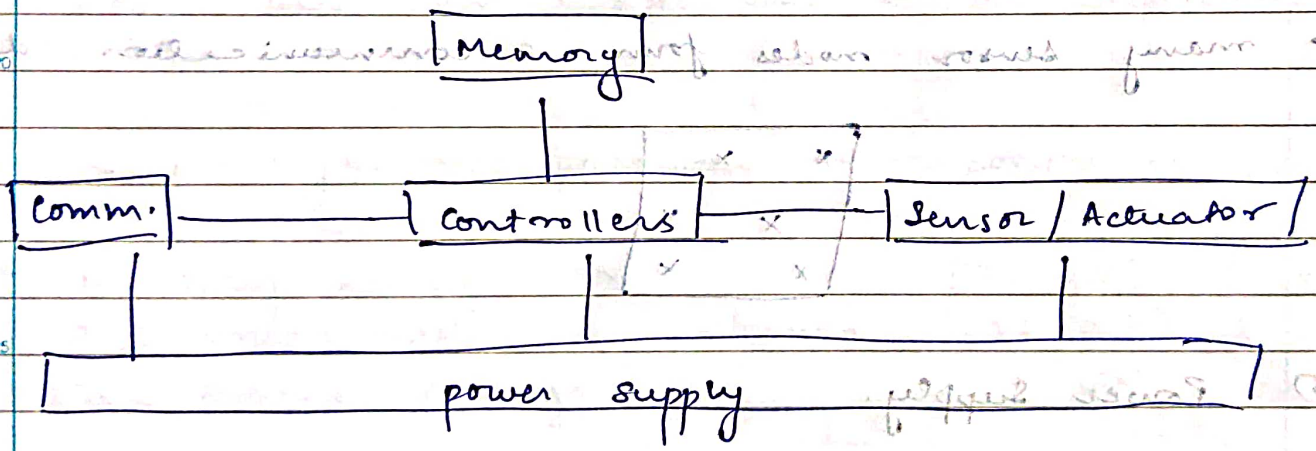
- In this chapter, we will look at WSN architectures, sensor nodes, etc.

- Sensor nodes or Mote is the most imp part.

computation	→ Processors	custom devices or equipments
storage	→ Memory	
Comm.	→ Modulation tech.	
Actuation	→ sensors or devices	

- There must be an associated power supply to a mote. It can be batteries or wired supply or solar / wind energy, etc.

Sensor Node Architecture (Hardware architecture)



(1) Controllers

- has the ability to process data and arbitrary code.

Date :

- the controlling action provides an actuating signal, and done through actuator. The real life parameter measurement is done by sensors.

(2) Memory

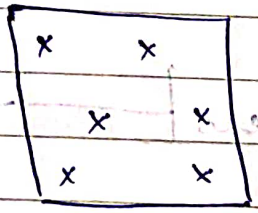
- used in storing the data.
- memory type depends on the WSN application and changes as application changes.

(3) Sensor / Actuator

- Sensors sense the info from physical world. While actuator make an intelligent decision based on the info & gather

(4) Comm. devices.

- many sensor nodes form as communication device



(5) Power Supply.

- includes batteries, wired supply and also clean energy forms. These clean energy can also be used to recharge batteries.

Date :

Advan Processors

~~advantages : less power req.~~

- Micro controllers are one type. These are now replacing PCs as embedded systems.

Advantages : less power supply req.
flexible programming
prog. are readable to DSP.

- DSP : digital signal processor.

Adv : are suitable for handling large vector data.

- FPGA : Field Programmable Gate Array
ASICs : Application Specific Integrated circuits

Adv : used for specific and dedicated task
Dis Adv : complex.

- Examples of ~~micro processor~~ micro controller (MC) :

1. Intel's Strong RAM (32 bit) } RISC architecture
2. Texas Instruments MSP430 (16 Bit) }
3. Airnel ATmega (8 bit)

Memory

(PTO)

Memory → Volatile → RAM → contents are lost as power is off

Memory → Non volatile → ROM, EEROM, flash Memory

ROM, EEROM → data in bits or bytes

flash Memory → Adv: taken data in blocks

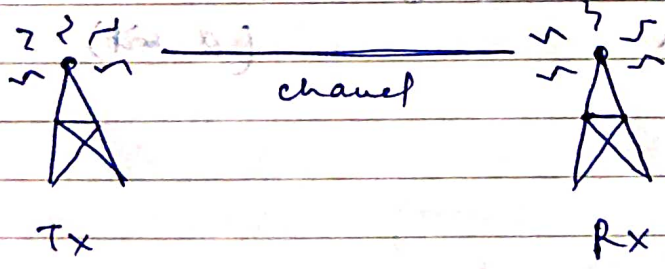
Dis adv: – complex ckt
– long read & write delay

Comm. device

comm. device → Transmitter (Tx), Reciever (Rx) : Transceivers
comm. device → channel → wired, wireless

wired:
- field bus
- profibus

wireless:
- radiowaves
- Ultrasound
- optical
- ultraviolet band



both works as Tx & Rx (though not simultaneously)

ship for WSN

Date :

- Modulation is also 2 types — analog, digital (preferred)

- Radio waves are the most preferred wireless channel.

Adv: - doesn't rely on line of sight
- long dist use cases
- high data rate
- low bit-error rate

- Optical comm. ← LED : electrical signal → light
  photodiode : light → electrical signal
  → channel : transmitted via light.

~~⇒ Transmitter~~

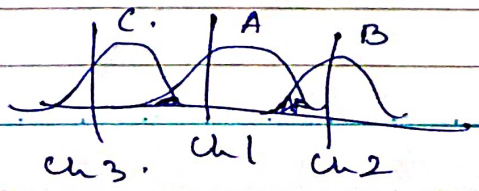
⇒ Transceivers task.

~~• task done:~~

1. service to upper layers (like MAC layer)
2. power consumption & energy efficient — power is off in sleeping stage.
3. carrier freq and multiple channels — modulated signal freq must match with channel freq.

restrict interference of other signal

FDMA
CSMA.



channel freq is centered around carrier freq.

Date :

4. State change time & energy

→ There is a change of state whenever transciever come out of sleeping state to active state.
time &
→ Min. energy req. for change of state.

5. Data Rate

→ transcievers need to provide high data rates.

6. Modulation

→ Digital modulations like FSK, ASK are most used nowadays.

7. Coding

8. Power control

→ Transciever power must be regulated in discrete fashion for power control.

9. Noise figure.

→ its the ratio of SNR in i/p device to the SNR in o/p device

$$\therefore NF = \frac{(SNR)_i}{(SNR)_o}$$

$$(NF)_{dB} = 10 \log \left[\frac{(SNR)_i}{(SNR)_o} \right]$$

→ Nf should be low

Date :

10. Gain

→ Gain = $\frac{\text{o/p signal}}{\text{i/p signal}}$

→ it has to be > 1. This leads to energy efficiency.

11. Power efficiency

→ ratio of radiated power to overall power consumed by front end.

12. Receiver sensitivity

→ Bit error rate = $\frac{E_b}{N_0}$ → energy per bit
→ noise of white gaussian light

↳ must be > 1.

→ indicates the min power req. by receiver to accurately get data or to work for broader range

13. Blocking performance

→ it should be high to block unwanted signals.

14. Carrier sense & RSSI

→ RSSI :
CSI :
(more accurate)

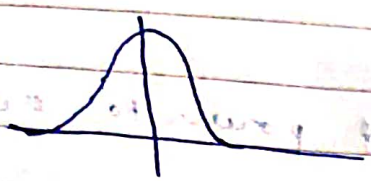
} info gathered from WSN

→ CSI is more accurate but req. complex data collection

→ RSSI is mostly used since its easy to gather info. It indicates how by data is accurately received with known transmitter power.

15. Freq. stability

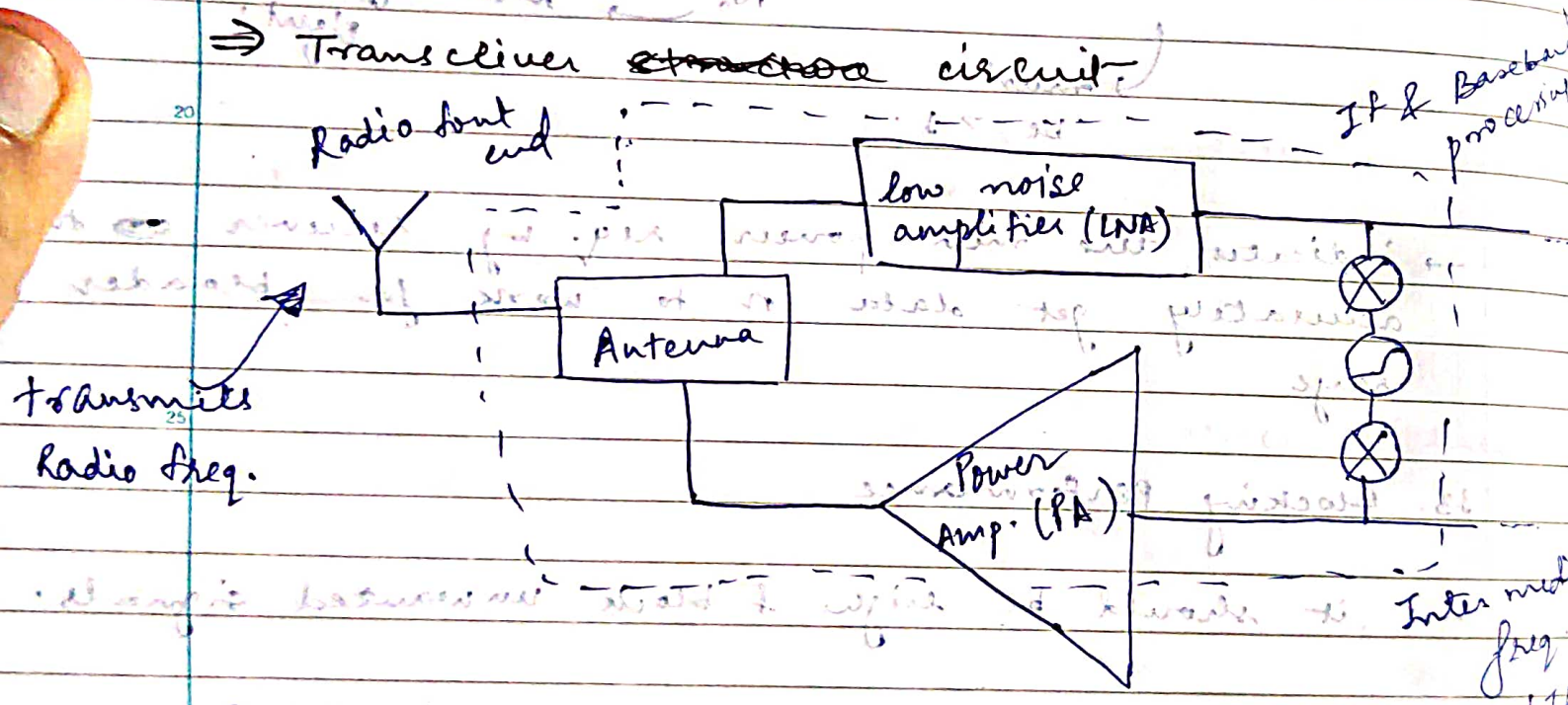
→



it should not change if there are any environmental change.

16. Voltage req. range.

⇒ Transceiver ~~circuit~~ circuit



Baseband processing : low freq.

Date :

- Entire transceivers consists of 2 parts
  - → Radio freq. font end : Analog signal processing part
  - → Baseband part : Digital signal processing part.

- ⊗ → mixer ◎ → LO / VCO {O : oscillator}

Req. in order to Radio freq (RF) signal to Baseband signal.

- utility of analogy to digital converter
  digital to analog

⇒ Operation of transceivers (radio)

1. Transit : Transmitter section is active
2. Receive : Receiver section "
3. Idle : happens at recievers end. Here, reciever is ready to recieve but there is no data for recieving.
   eg. Synchronization circuit
   - Aquisition → active forever
   - Tracking → can be idle.
4. Sleep : Transceiver is powered off, when not in use.

entire config & initialization is done every time, transceiver is in use.

sleep < deep sleep ~~(permanent)~~
temporary sleep. → some are already saved & not to be re-done.

Advanced Radio / Transceivers

- few eg. of advanced radio :-

Advanced Radio

RF wireless comm.
- wakeup Radio
- DSSS
- Ultra wide Band

Non RF wireless comm.
- optical
- ultrasound.

- wakeup radio has some receiver ckt that create an event (reception of data).

reception of data < Yes — event = 1 — receiver: on
No — " = 0 " : off.

detection

This doesn't req. any power.

If event is detected the main receiver is powered on to receive the pack.

Adv: it properly manages receiver power

Date :

- DSSS : Direct sequence Spread Spectrum.

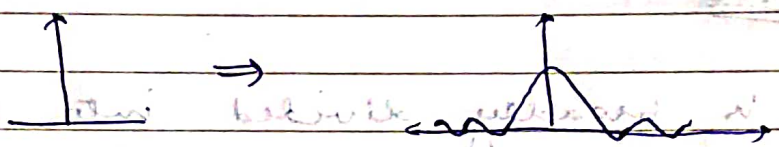
  max.

  Adv : It reduces ~~[illegible]~~, interference ~~to a maximum~~ Conventional ASK, FSK model arent used.

  Dis Adv : It is quite complex due to larger bandwidth. ⇒ not much used in WSN only in Military.

- (A) Ultra white Band (UWB Radio)

  It has broad freq. range. (Adv)



  Impulse

  Short width pulse are transmits ⇒ power req is small (Adv)

  ⇓

  Since power supply is less, so it may get affected by noise (Dis Adv)

  It has high data rate in short range. (Adv)
  Circuit is small & easy (Adv)

  It has synchronization issue (Dis Adv).

- Optical comm

  Adv : high data rate, less $\frac{E_b}{N_0}$, simplicity

DisAdv: it has line of sight issue → comm. can be affected due to weather

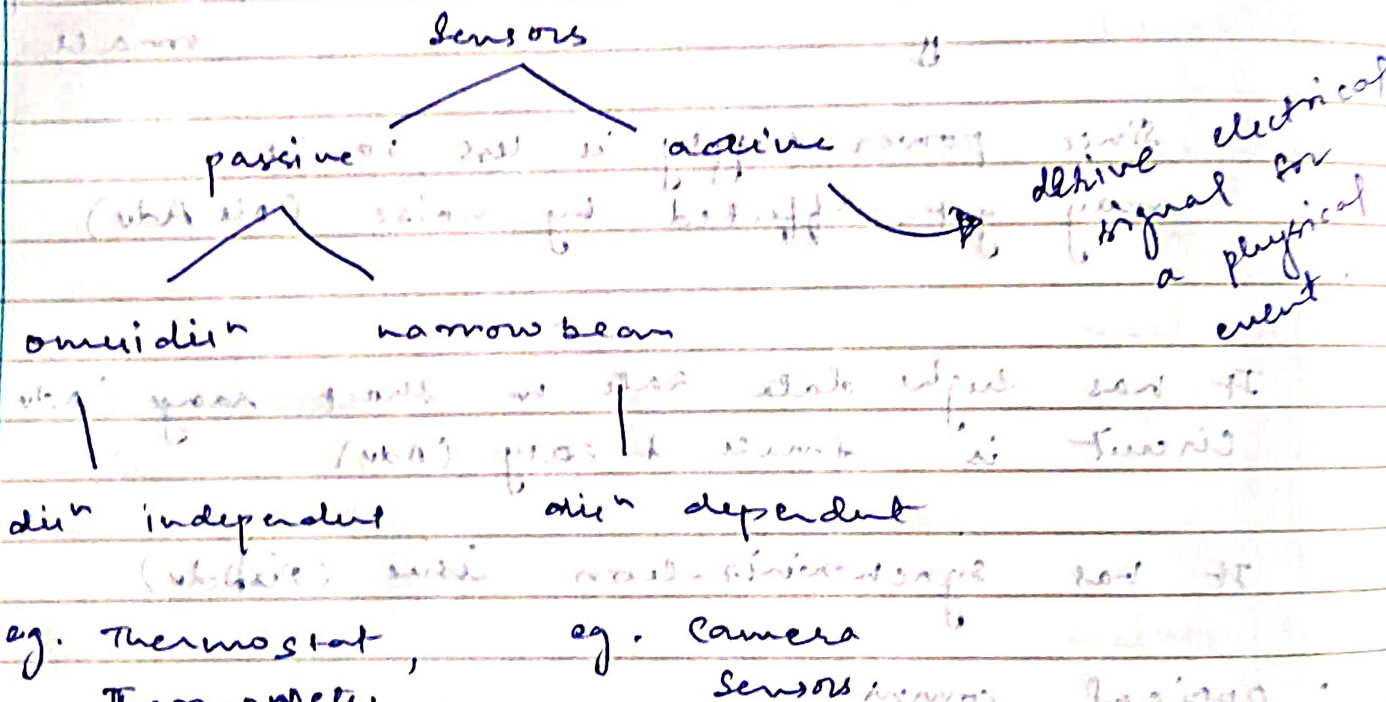
↳ optical signal must penetrate through water

- Ultrasound

Adv: can be transmitted via long distance with small power.
Also can penetrate through water.

IoT Sensor

- Sensor is broadly divided into active and passive. Under passive sensors, we have omni dir^n & narrow beam (dir^n perspective)



directly convert electrical signal

Date :

- for temp measurement < Active (Thermocouple)
  passive (Thermometer)

Power Supply of sensor nodes

power supply

supplying power from sources (Primary source)

eg. Batteries

replenishing consumed power from other nodes/ device. called Energy scavenging (secondary source)

eg. solar cells, fuel cells, energy from vibration; temp gradient (diff). etc.

some of critical functional parameter a battery need to consider :

- capacity (J/cm^3) : high.
- capacity per load : high (to handle various variety of task done by nodes)
- efficient recharging : high
- self discharging : low

- These unconventional secondary energy sources will consume energy and act as secondary energy src, is called energy scavenging.

- Issues in sec. src -

→ discharging of fuel cells
→ Temp diff < 5
→ less vibration