Industrial Automation & Control

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Gyan Ranjan Biswal received his B.E. in Electronics Engineering from the Pt. Ravishankar Shukla University, India in 1999 and M. Tech. (Honors) in Instrumentation & Control Engineering from the Chhattisgarh Swami Vivekananda Technical University, India in 2009 followed by Ph.D. in Electrical Engineering, specialized in the area of Power System Instrumentation (Power Generation Automation) from the Indian Institute of Technology Roorkee, India in 2013.

He is expertise in Design and Development of cooling systems for large size electrical generators, and the C&I of process industries. He has been in academia for about twelve years. Presently, he is with VSS University of Technology, Burla, India at the capacity of Associate Professor, EEE from Dec. 2016, and HOD, EEE from Jan. 2020 to Feb. 2023, and conferred with the Best faculty Award for the AY 2021-22 under Professor/ Associate Professor category . He has more than 75 publications in various Journals and Conferences of Internationally repute to his credit. He also holds a patent as well, and filed one more. He also adapted one international edition book published by Pearson India. He received research grants of US $80,000 (INR 64 lakhs). He has been supervised 02 Ph.D. theses and 09 Masters' theses, and ongoing 03 PhD theses. He has also been recognized with many national and international awards by elite bodies. He has been awarded with CICS award under the head of Indian National Science Academy for travel support to USA, MHRD Fellowship by Govt. of India, and Gopabandhu Das Scholarship in his career. His major areas of interests are Power System Instrumentation, Industrial Automation, Robust and Intelligent Control, the Smart Sensors, IoT enabled Smart Sensors, the Smart Grid, Fuel Cell lead Sustainable Sources of Energy, and System Reliability.

Dr. Biswal is a Fellow IE (India), Senior Member of IEEE, USA, and Life Member of ISTE, India. He is actively involved in review panels of different societies of international repute viz. IEEE, IFAC, and the ISA. Currently, he is also actively involved as a Member of IEEE–SA (Standards Association) working groups; IEEE P1876 WG, IEEE P21451-001 WG, and IEEE P1415. He has also been invited for delivering guest lectures at World Congress on Sustainable Technologies (WCST) Conf. 2012, London, UK, INDICON 2015, New Delhi, India, National Power Training Institute (NPTI), Nangal, India, and G.B. Pant Engineering College, Pauri, Gharwal, India, Surendra Sai University of Technology, Burla, as a guest expert in 2016 IEEE PES General Meeting Boston, MA, USA, 1st Annual Webinar of Complex Engineering System, Politecnico di Milano, Italy in 2022, and Keynote lecture in 12th EAI International Conference on Sensor Systems and Software, Portugal in 2021

Syllabus

Industrial Automation & Control

MODULE-I (7 HOURS)

Introduction to process dynamics, its type and classifications. Control actions and controller tuning: Basic control actions-on/off, P, P+I, P+I+D, floating control, pneumatic and electronic controllers, controller tuning.

MODULE-II (7 HOURS)

Introduction to PLC, PAC, DCS and SCADA. IEDs, RTUs, HMI, Smart Sensors and Actuators. Communication Networks for PLC. The Instrument Lists of PLC and HMI. System Architecture, Programming languages of PLC, Relay logic and Ladder logic, Ladder Diagram Elements.

MODULE-III (9 HOURS)

Computer controlled processes: PLC based control of different types of processes such as liquid level system and flow control, open-and-closed chamber pressure control, temperature control, different types of heat exchangers.

MODULE-IV (9 HOURS)

Physical Ladder Diagram and Programmable Ladder Diagram. Case Studies: frost free refrigerator / freezer system; composite discrete / continuous control; conveyor system; oven system; elevator system; uniformly heated liquid control system, and hydro-phonic system.

MODULE-V (7 HOURS)

Advances in Automation: Programmable Automation Controllers. NI my-DAQ, my-RIO, c-RIO, and ELVIS. IEEE 802.11 / 15 Standards, IEEE 1451.5 Std. Role of Internet of Things and Cyber Physical System in Industry Automation, MQTT protocol.

Text and Reference Books

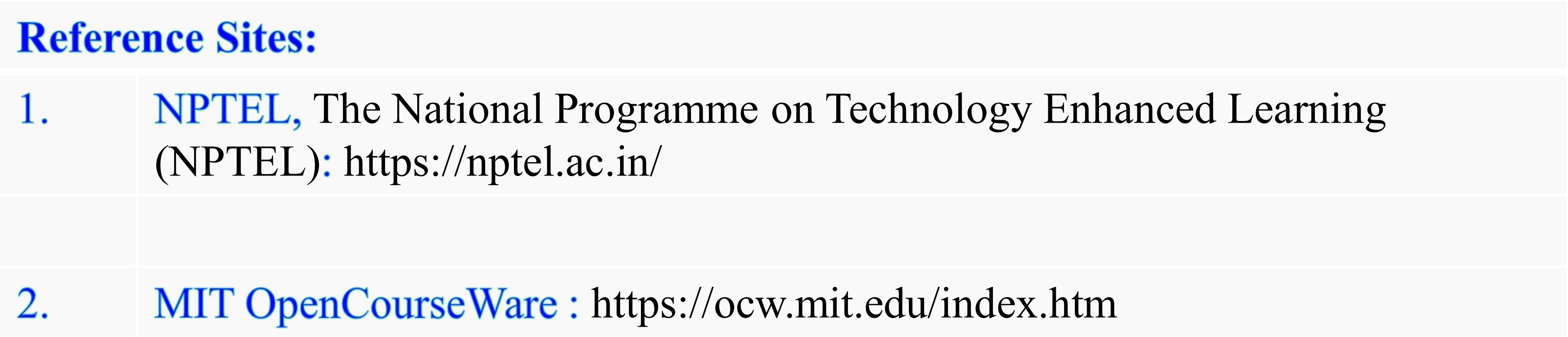
Recommended Text Books:

1. Peter D. Harriot, “Process Control”, Tata McGraw-Hill, New Delhi, 2009.
2. Liptak, H. “Process Control: Instruments Engineer’s Handbook”, Butterwirth Heinemann, 1995.
3. Curtis D. Johnson, “Process Control and Industrial Technology”, Pearson India, 8th ed., 2012.

Reference Books:

* Norman A Anderson, “Instrumentation for Process Measurement and Control”, CRC Press, 2018.
* B. Wayne Bequette, “Process Control – Modeling, Design, and Simulation”, Pearson India, 2015.
* John W. Webbs, “Programmable Logic Controllers – Principals and Applications”, fifth Edition, Pearson India /PHI (Old edition), 2012.

Other Important References



Reference Sites:

1. NPTEL, The National Programme on Technology Enhanced Learning (NPTEL): https://nptel.ac.in/

2. MIT OpenCourseWare : https://ocw.mit.edu/index.htm

Course Outcomes

Upon successful completion of this course, you (students) will be able to

CO1	Understand the basic principles and importance of process control applications using automation.
CO2	Enlist the required instrumentation, knowledge of the P&ID, the Instrumentation Lists, and final elements to ensure that well-tuned control is achieved.
CO3	Demonstrate the student’s ability to pursue a career in electrical engineering, control systems, automation platforms through a diverse range of theoretical skills and practical experience of real time applications.
CO4	Plan, design, install, operate, control and maintain different process and automated applications using PLCs/PACs. Further, PLC / PAC algorithm using Ladder Logic Diagram or equivalent languages while handling a plant process.
CO5	Implement an automation platform such as PACs and IoT while handling a plant process.

Introduction

Cluster	Component	% out of 100
1.	Test 1 & Test 2	**05+05=10**
2.	Mid-Sem Exam	**30**
3.	End-Sem Exam	**50**
4.	Assignments	**05**
5.	Teacher’s / internal (tutorial / case studies) assessment or Attendance	**05**
	Total	**100**

Note: * Exams can be of subjective and/or objective type.

Programmable Automation Controllers

- Sensor networking: Wired and Wireless

Wired Network Protocols

- RS-232
- RS-485
- Modbus: RTU and ASCII modes
- Foundation Fieldbus
- Profibus / Profinet
- CAN
- Ethernet/IP
- HART
- LAN

Wireless Network Protocols

- WLAN: DSSS, FHSS – ISM band
- Wi – Fi (IEEE 802.11)
- Bluetooth (IEEE 802.15.1)
- Zigbee (IEEE 802.15.4)
- WiMAX (IEEE 802.16e)
- MBWA (IEEE 802.20)
- WRAN (IEEE 802.15.1)
- Wireless HART (IEEE 802.15.1)/ ISA 100.11a
- IEEE 1451.4/.5

Technology (Standard/ Protocol)

Urban/ Industrial Measurement

❖ System architecture of communication/ sensor networks

- Low latency or end-to-end delay
- Long battery life or low power consumption
- High network reliability
- High data security
- Low BW

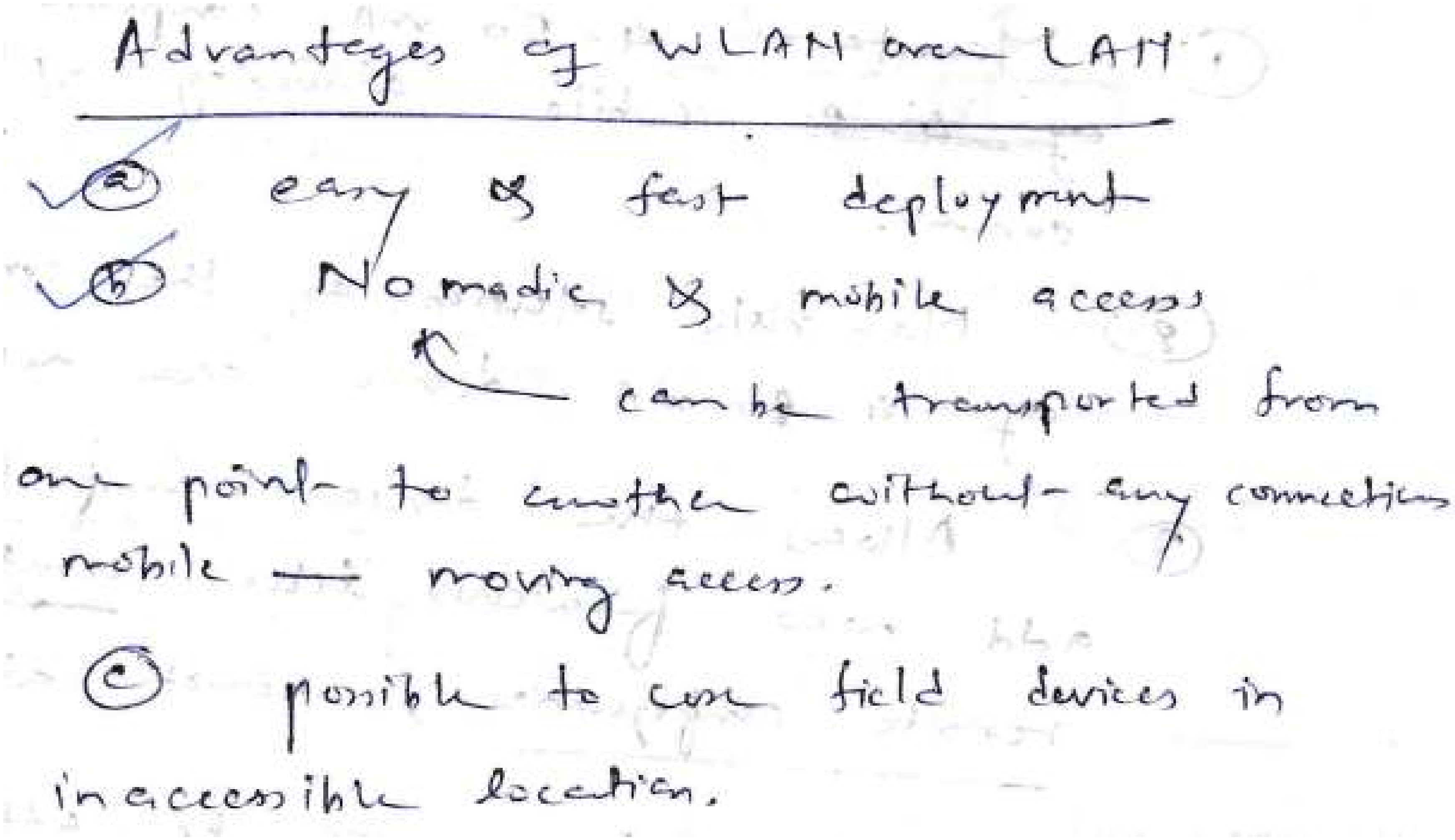
❖ Specifications of a smart sensor

- Sensitivity
- Low power consumption
- High Q-factor
- Dielectric constant
- Impedance function
- Dissipation factor etc…

✓ Current Research on IoT Enabled Smart Sensors

Wireless Network Protocols

WLAN



Advantages of WLAN over LAN.

✓ ⓐ easy & fast deployment

✓ ⓑ Nomadic & mobile access

can be transported from one point to another without any connection

mobile → moving access.

ⓒ possible to use field devices in inaccessible location.

Major issues:

(a) Data security against noise & interference

(b) Data security against interception & eaves dropping

- may be able to catch the signal but must not be able to decode the data.
- dropping is unintended interception

(c) Data security against jamming

WLAN Technologies :

- Media – Infrared → IRLAN
  - – Radiowaves → Spread Spectrum n/w
    - → Narrowband n/w LAN,

- **IRLAN** → ① restricted to only single room.

  ② allows only LOS commn.

  ③ distance range will be 10-50 m.

  i.e 0 - 10 m or 0 - 50 m.

  ④ Data rate is low / medium.

  1 – 10 Mbps (max. rate 10Mbp)

  ⑤ very limited application.

- Narrowband μw LAN

① μw → > 1 GHz

② uses only the min. BW required for transmission.

③ range is 10 - 50m.

④ Data rate is 10 - 20 Mbps.

⑤ Data security is very poor & therefore it's rarely used.

- Spread Spectrum μw LAN

① Freq. Hopping Spread Spectrum (FH-SS)

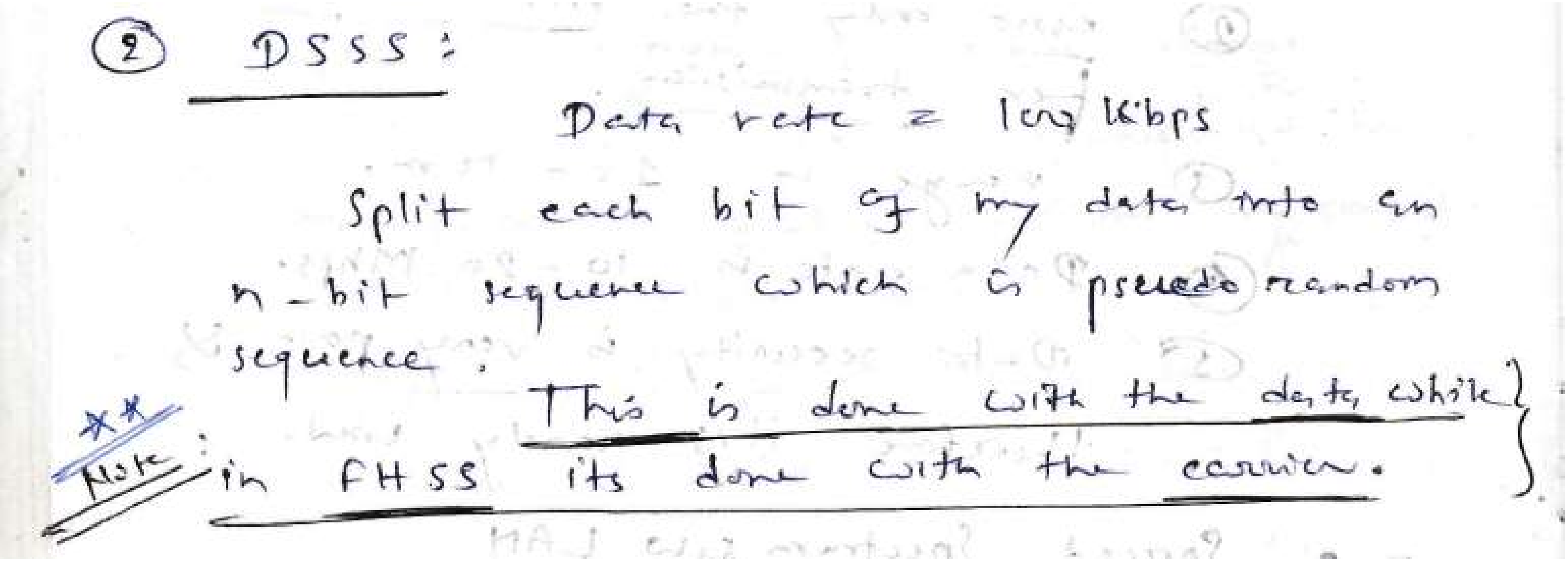
② Direct Sequence " " (DS-SS).

① FHSS :

- No. of carrier freq. are used : 10 – 100 }

I. 2, 000, 000 kHz
II. · , 100 kHz
III. ' , 200 kHz
| | |
| | |
XXX. 2, 003, 000 kHz

jumping from one carrier to another is known as freq. hoping. The freq. hoping (FH) is done in a pseudo random manner.



② DSSS :

Data rate = 1024 kbps

Split each bit of my data into an n-bit sequence which is pseudo random sequence.

** Note : This is done with the data while in FHSS its done with the carrier.

* • ISM Bands :

→ Industrial Scientific & Medical

→ License free band

- ⓐ 900 MHz band   Around 900 MHz
- ⓑ 2.4 GHz band   2.4 – 2.5 GHz
- ⓒ 5.0 GHz band   5 – 6 GHz

• Higher freq. ↔ More LOS Commn

* WIRELESS NETWORK PROTOCOL

Technology over / Standards or protocol

1. Wi-Fi over / IEEE 802.11 → name of work group
2. Bluetooth over / IEEE 802.15.1
3. Zigbee over / IEEE 802.15.4
4. WiMax over / IEEE 802.16
5. MBWA over / IEEE 802.20
6. WRAN over / IEEE 802.22
7. Wireless HART over IEEE 802.15.4 / (ISA 100.11a)

- Wireless HART – Industrial / Robust environment applications
- Zigbee - Smooth / soft environment
- Wi – Fi – commercial applications

Inside Control Room

- Bluetooth – Computer to peripheral at room / office / mobile
- Wi-Max – commercial offices for business monitoring

Wi – Fi

(IEEE 802.11)

① Wi-Fi / IEEE 802.11

Wi-Fi → Wireless fidelity

802.11 → IEEE Std. called Wireless LAN Standard

LAN std. → family of standards

Wifi Alliance → 802.11, 802.11a, ~~802.11~~, 802.11b, 802.11g

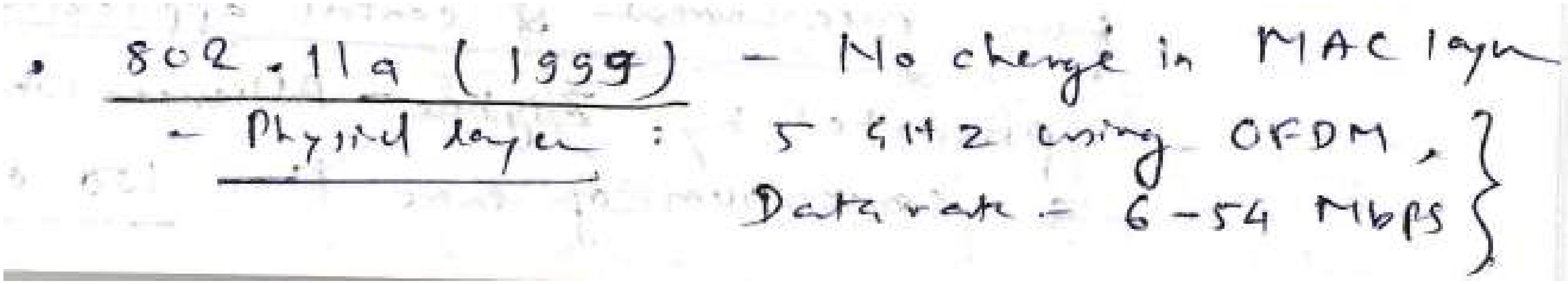
- IEEE 802.11 (1997) — specifies two layers only.

ⓐ MAC layer : media access control layer

ⓑ Physical layer

→ specifies three tx'an media.

	Wavelength/freq.	Data Rates
IR :	850 – 950 nm	1, 2 Mbps
μW :	2.4 GHz (FHSS)	1, 2 Mbps
	2.4 GHz (DSSS)	1, 2 Mbps



- 802.11a (1999) – No change in MAC layer
  - Physical layer : 5 GHz using OFDM, Data rate = 6 – 54 Mbps }

Note:

- Wi-Fi only supports star topology.
- Comparing OFDM with FHSS ,the data security is not as high as FHSS.
- While using OFDM Data-rate is high i.e. Data Rate **->**1/Data security.

- 802.11b(1999)

Physical Layer: 2.4 GHz-Using DSSS, allows data rate = 5.5, 11 Mbps

Note: Wi-fi only supports star topology.

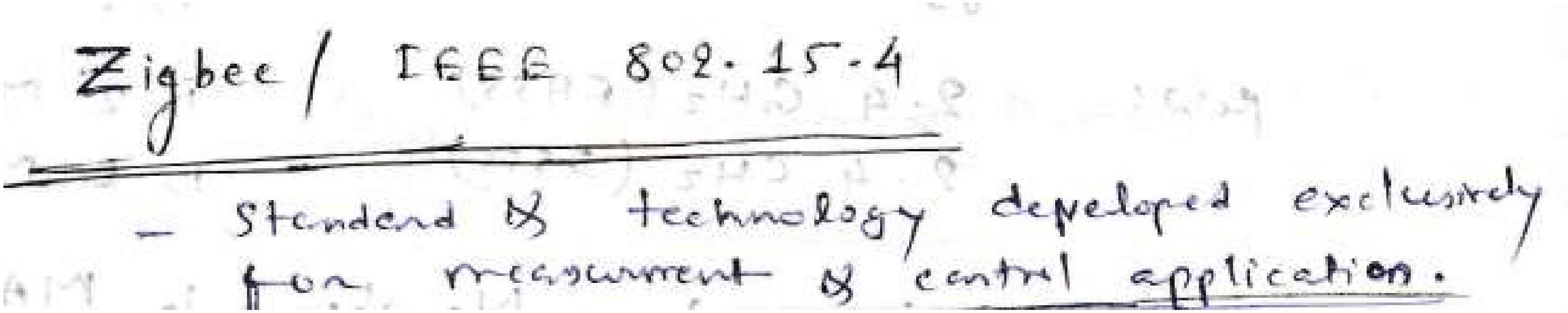
comparing OFDM with FHSS, the data security is not as high as FHSS. while using OFDM datarate is high.

★ (i.e. datarate $\propto \frac{1}{\text{data security}}$)

- 802.11b (1999)

Physical layer: 2.4 GHz — using DSSS, allows data rate = 5.5, 11 Mbps.

Zigbee (IEEE 802.15.4)

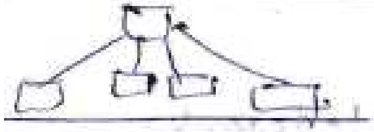


Zigbee / IEEE 802.15.4

– Standard & technology developed exclusively for measurement & control application.

❖ Standard technology developed exclusively for measurement and control applications.

- Two protocols: Ethernet and MAC



∵ Ethernet – 100 Mbps
∵ Wifi – g+ = 54×2 = 108 Mbps.

– **Name:** "Low Rate Wireless PAN Standard"

This standard defines MAC layer & physical layer }

- **Important features:**

① low frequency
② long battery life
③ high data security
④ low data rate / BW upto 256 kbps.

- MAC protocol

  CSMA / CA – collision avoidance

- physical layer : Defines as follows

- Freq. Bands : ① ISM – 900 MHz → {data rate = 20, 40 kbps; ch. BW : 200 MHz}

  ② ISM – 2.4 GHz → {ch. BW : 500 MHz; data rate : 250 kbps}

- Tx^{ion} methods : DSSS → can go for TDM, as data rate req. is low.

- Tx^{n} power ⩾ 1 mW

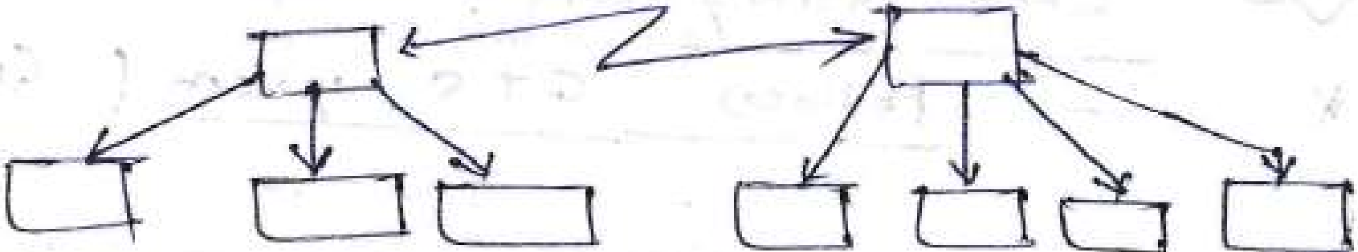
- Range atleast 10 m, ⩾ 10 m. so one can contention

- Topologies specified: ① Star – cannot comm^n independently.

② Mesh – allows ~~peek~~ peer to peer comm^n. Any node can communicate with other node.

* Adv^n of Zigbee

Also, allows Ad-hoc N/W means that any node can be added / removed without affecting the whole N/W.



MANET : Mobile Ad-hoc Networks

- **MAC layer - IEEE 802.15.4 :**

It recognises two types of devices :

① Full function Device (FFD).

- can function as a normal device or as a N/W coordinator

② Reduced Function Device (RFD)

- can function only as a normal device and 'not' as a network coordinator.

- Role of N/W co-ordinator :-

① Initiates all commn.

② Can communicate with any device in the N/W.

③ Can ~~to~~ transmit beacon.

MAC layer : Three types of data are specified :

① **Periodic data :**

- Becon sent by N/W coordinator & other nodes will send the data periodically otherwise it will go to sleep mode
- latency high, power saving - low.

② **Intermediate data :**

- NC sends message as & when necessary.
- That node on addressed node sends
- low latency, large power saving

③ **Low latency data :**

* - follows GTS system (Guranteed Time Slot)

- Each node is guarenteed to have a time slot whether master ask it or not.
- Zero latency, large power saving
- there are node itself can initiate the commun as compared with intermediate data!

Data Security – very high

Zigbee ? Wi – Fi

- Comparision

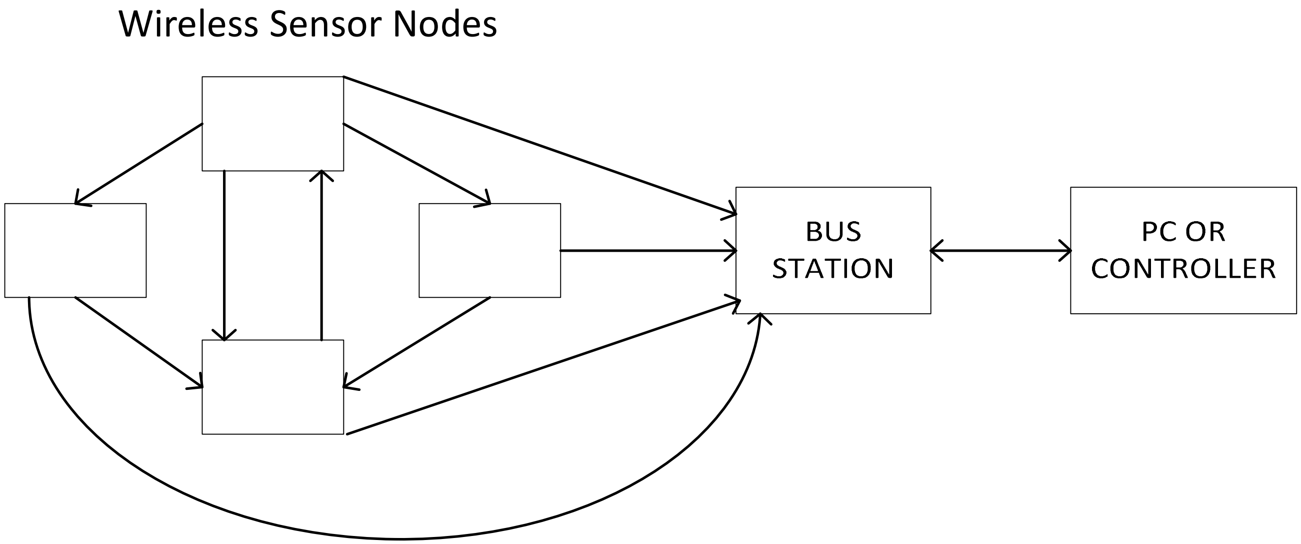
	Zigbee	WiFi
① MAC layer	CSMA/CA collision avoidance	CSMA (collision may take place)
② Tx^{ion} media	ISM 900 ISM 2.4	ISM 2.4 " 5
③ Tx^{ion} Technique	DSSS	FHSS, DSSS, OFDM
④ Tx^{er} power	≥ 1 mW.	High (not specified)
⑤ Topology	• Star • Mesh	• Star
⑥ Data rate	upto 250 Kbps (low)	upto 54 Mbps (High)
⑦ ~~Large~~ Range	10m to 100m (low)	100m – 1 km (High)
⑧ Power cost	High	Low
⑨ Latency	Low	High
⑩ Power requirement	• Low	High.

Some Other Points Needs Attention

Wireless Sensor Network

Three components:

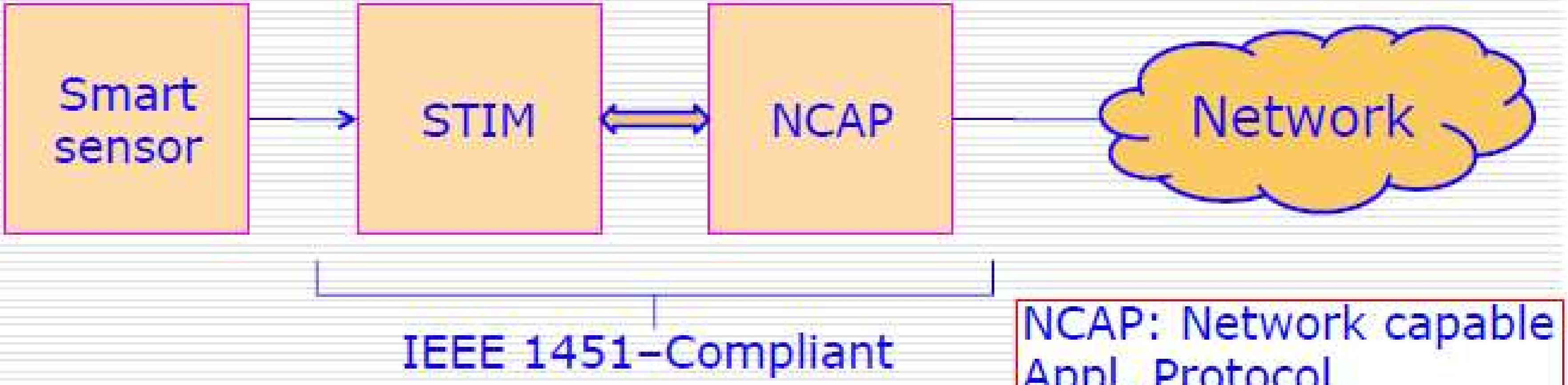
1. Wireless Sensor Nodes
2. Base Station-meant to collect data from all the nodes
3. PC/Controller



Wireless Sensor Node

1. Smart Sensor
2. Microcontroller
3. Wireless Transducer
4. Batteries (non Chargeable batteries of 1-10 years
5. Wireless sensor node is also called a “Note”

Smart Sensor + IEEE 1451 Interface



Smart sensor

STIM

NCAP

Network

IEEE 1451–Compliant

NCAP: Network capable Appl. Protocol

Advantages
- ❖ No SC required
- ❖ Flexibility of network protocol

Disadvantage
- ❖ Needs STIM & NCAP

Some of Recent Updates

❖ IEEE 1451 Standard

1. It standardizes the interface of smart transducers (sensors and/or actuators).
2. Smart transducers must have internal data sheets (specification on electronic datasheet) called TEDS.
3. Any standard of any output should be compatible with existing networks.

1451 is a ~~format~~ family of Stds.

→ any transducer can be connected to any network : Goal

+ IEEE 1451.1 →
.2 →
.3 →
.4 →
.5 →
} Issued

.6 →
.7 →
} Drafts

⟹ Note : all are compliant to the interfacing detail, not to the internal detail of ~~processor~~ transducer.

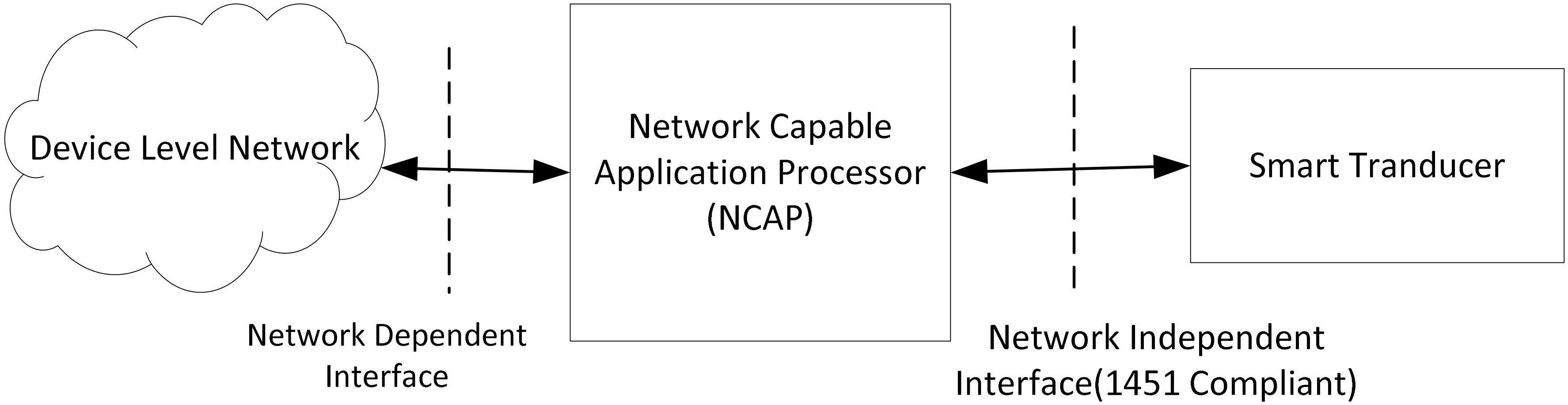
1451.2 : 1997

Title of IEEE 1451:

- Standard for Smart Transducer Interface for Sensors and Actuators

(i.e. How to interface ??? for sensor and actuators both)

Overall Picture of IEEE 1451



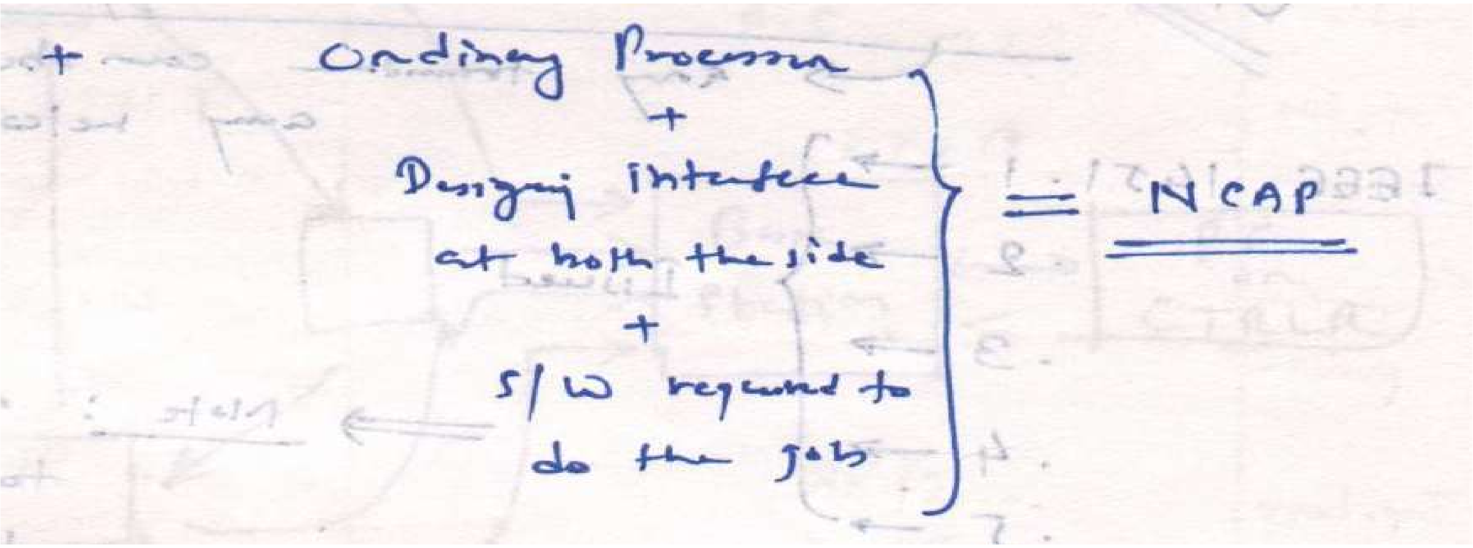
Device Level Network

Network Capable Application Processor (NCAP)

Smart Tranducer

Network Dependent Interface

Network Independent Interface(1451 Compliant)



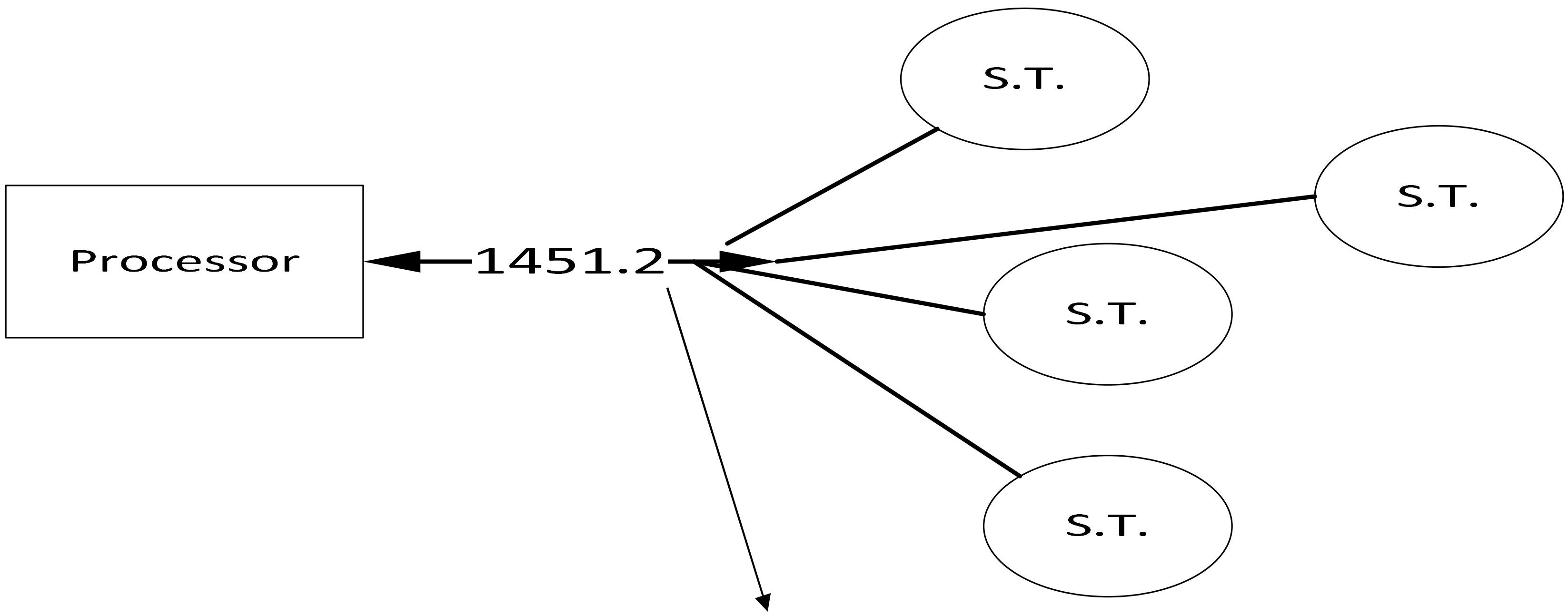
Ordinary Processor
+
Design interface
at both the side
+
S/W required to
do the job

= NCAP

1451.1 : Provide object model

(when every function of processor is treated as object i.e. both side interface + software itself)

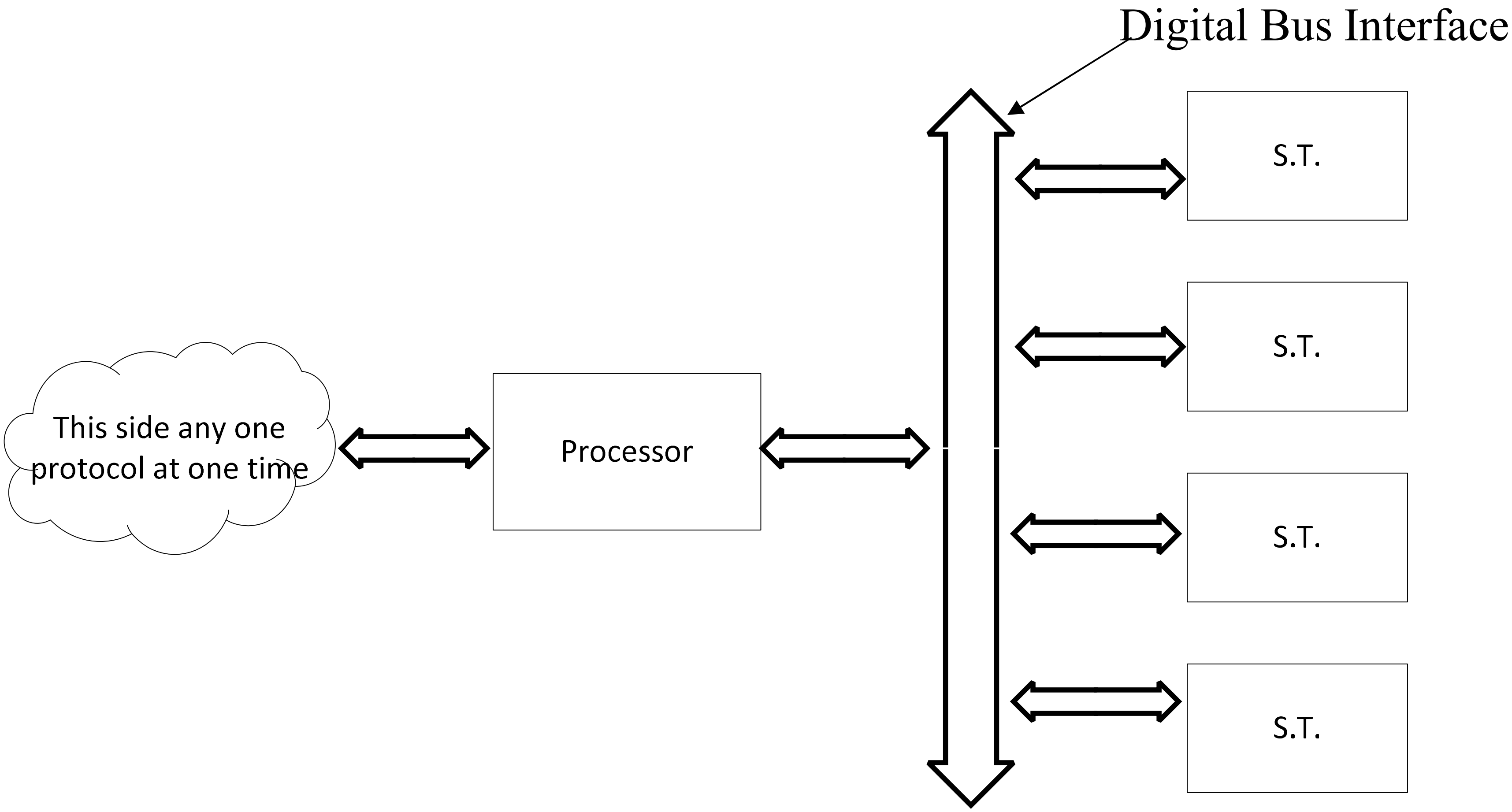
1451.2: Example: Typical 99% application (here, it has digital interface)



How to interface
all S.T.s are located
at one place.
(Pt. - to - Pt. comm)

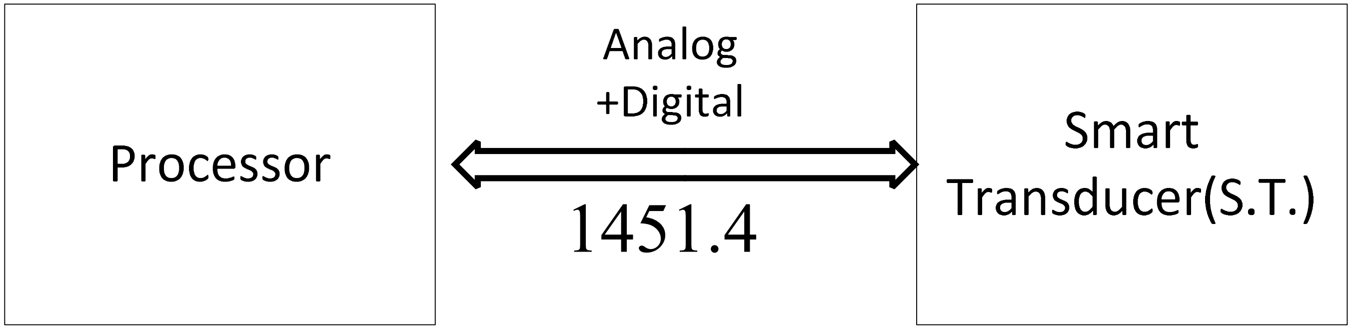
(i.e pt-to-
pt-
commn)

Example: IEEE 1451.3 (Multi Drop Distribution)
All S.T.s are distributed in a pant not located at one place

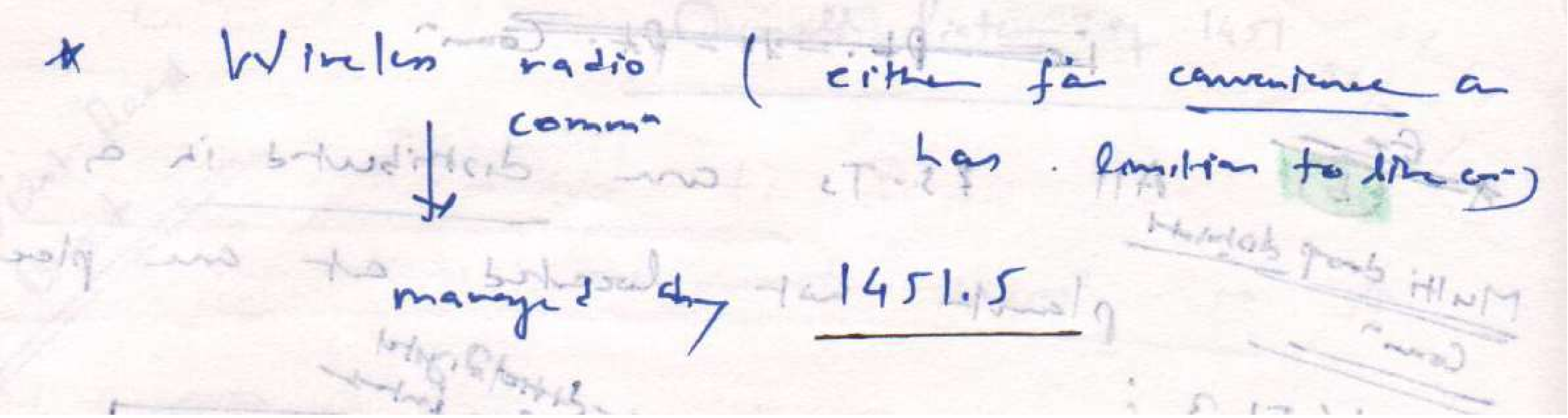


Transducer Bus (Multi Drop Bus Topology)

- Let we have a S.T. with Analog Output (1451.4) , again for point to point communication only.



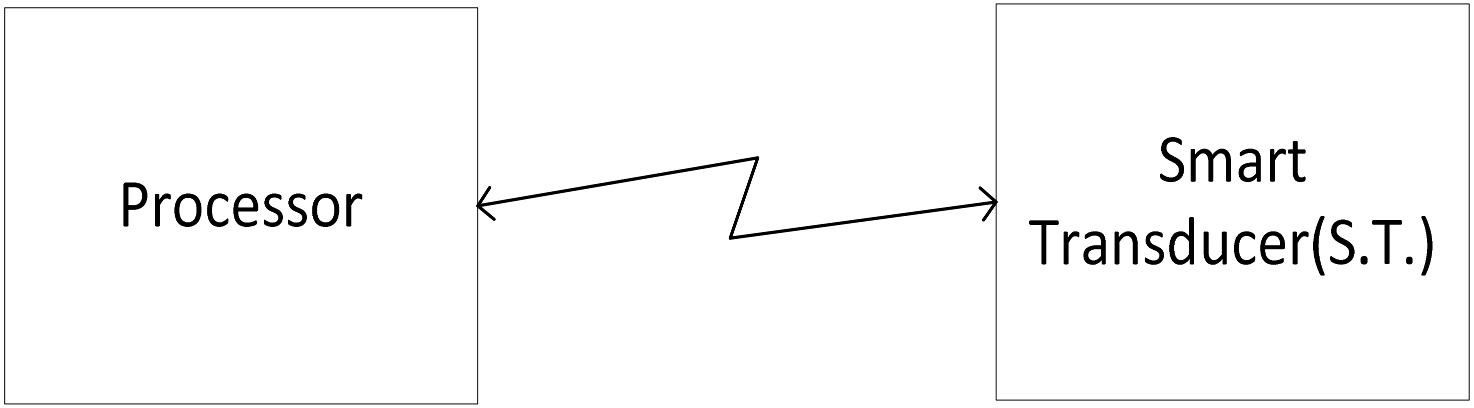
Note: If we have Analog + Digital interface (mix mode interface), point to point communication application together, then requires IEEE 1451.4



* Wireless radio comm^n (either for convenience or has limitation to wire con^n)

↓

managed by 1451.5



Processor

Smart Transducer(S.T.)

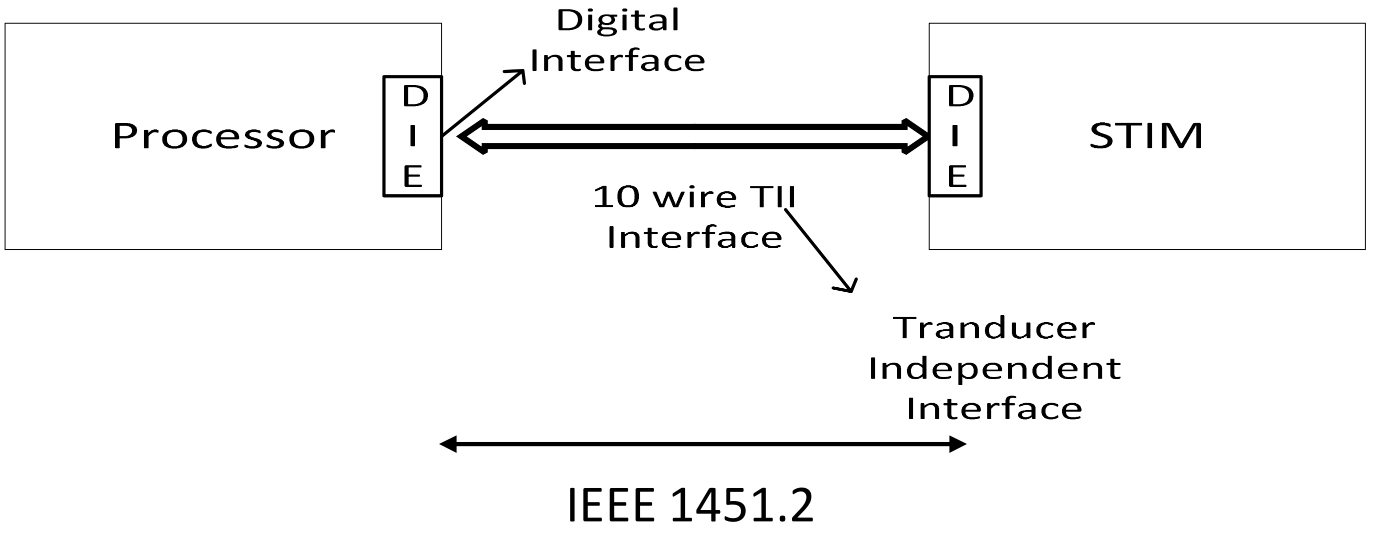
Details:

IEEE 1451.2(1997) : Subtitle is: “ Transducer to Microprocessor Communication Protocols and TEDS formats”

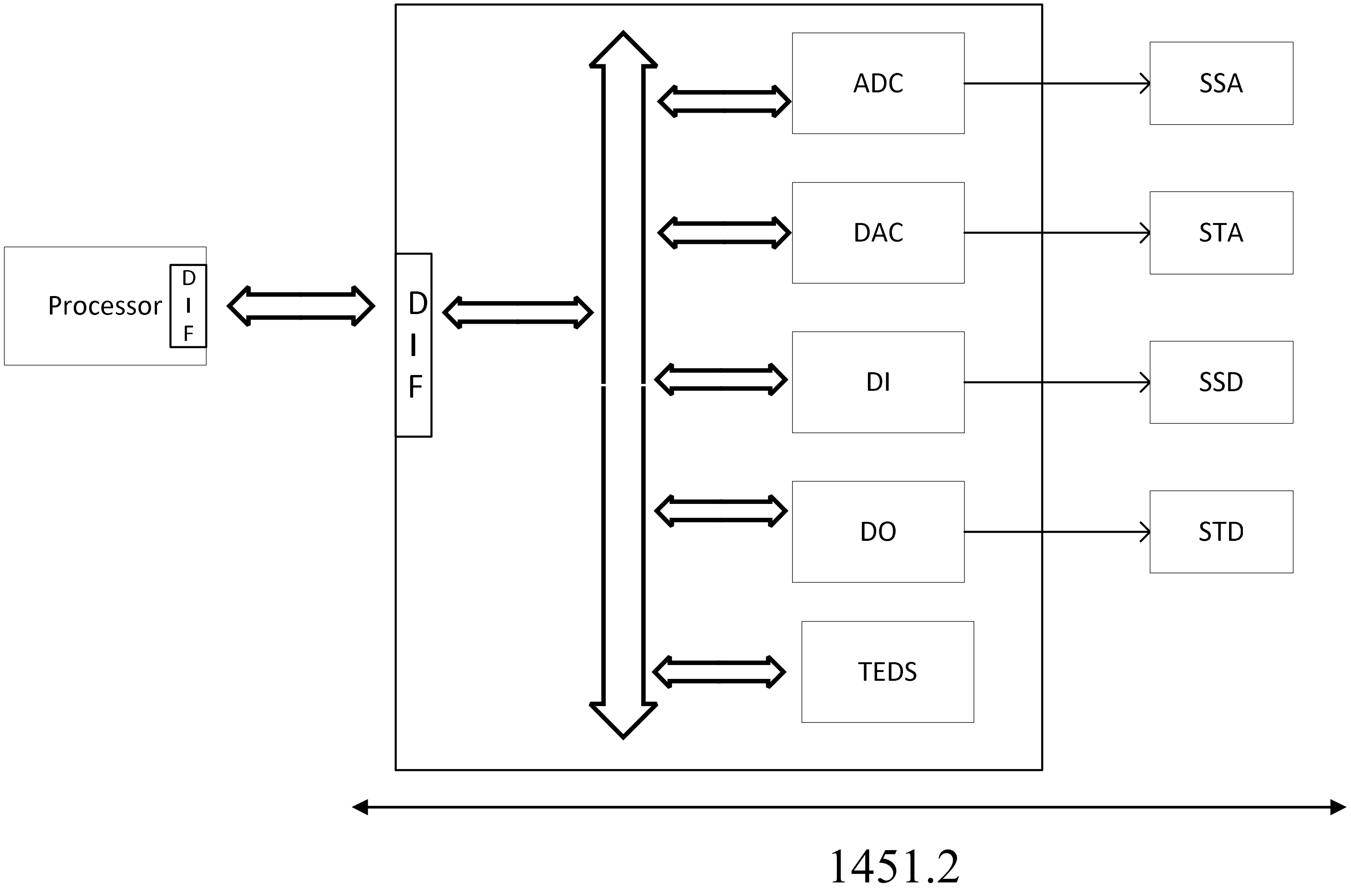
It deals with the interfacing of physically concentrated transducers i.e. specified to point to point communication i.e. all S.T. are at one point and processor at another point.

Specification:

1. Smart Transducer Interface Module (STIM)
2. STIM to processor communication Interface
3. Formats of TEDS
4. TEDS is Read Only Memory (EEPROM)



As all STs are located at one place, and there are 10 wires, obviously not used for long distance i.e. used of Short Distance Communication.



SSA –Smart Sensor with Analog Output
STA- Smart Sensor with Analog Input
SSD- Smart Sensor with Digital Output
STD- Smart Sensor with Digital Input

Functionality:

1. DIF to 10 wire interface
2. ADC from SSA to DIF (Control Signal)
3. DAC from DIF to STA (Control Signal)
4. Similarly for DI and DO

* TEDS

~~Data~~ specified in four parts.

common data → I - Meta TEDS: (common data applicable to all transducers), small amount of data.

individual data → II - Channel - TEDS: most of data comes from here

~~trans~~ channel → / No. of transducers that can be interfaced upto 1 - 255. individually.

III. Calibration - TEDS: calibration purpose (self calibration)

IV. Application - TEDS: Appl^n specific data.

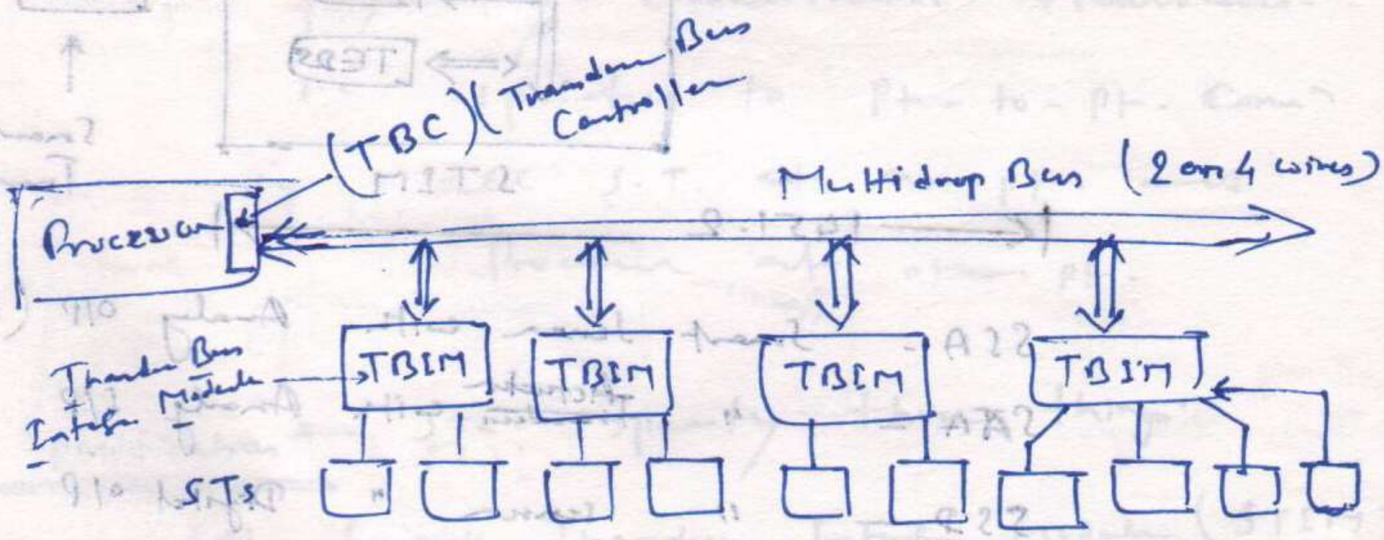
V. Extension TEDS: some memory that can be used in any other form at later stages.

i.e this std. specify.

1. DDR
2. ADC & DAC, DI, DO - mtr
3. TEDS

+IEEE 1451.3 : Subtitle : "Digital Communication and TEDS formats for Distributed Multidrop System"

(1451.3 – 2003)



this std specifies :

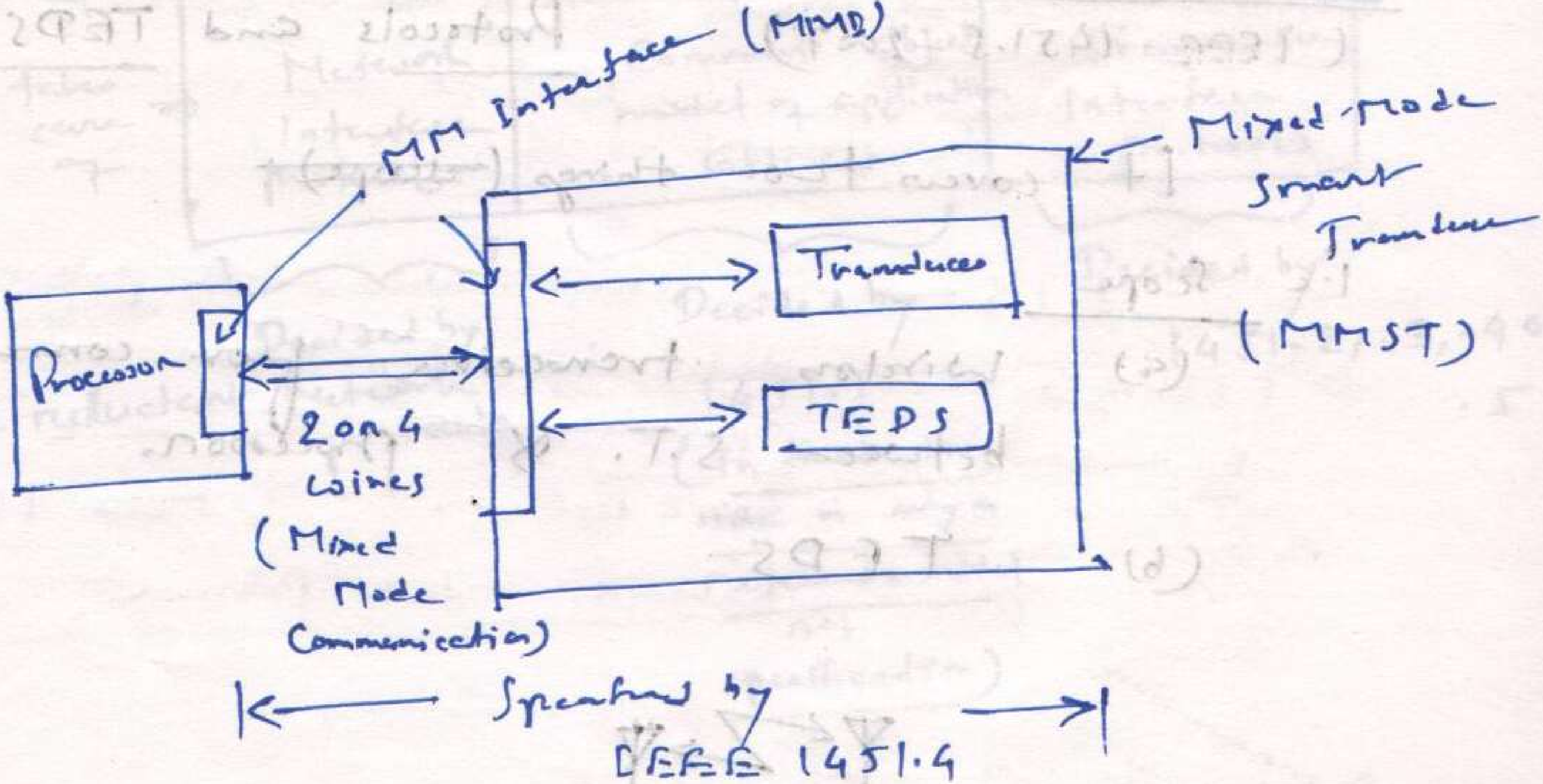
1. TBC
2. TBIM
3. Multidrop Bus
4. TEDS

* each TBIM can address 255 ~~Bus Interface~~ STs.

Benefit: 1451.3 is designed for long distances as meant for distributed system, and that is why 2/4 wire are given.

IEEE 1451.4 (2004) : Subtitle: “Mixed Mode Communication Protocols and TEDS Formats”

1. It is used for interfacing these STs , have both Analog and Digital data.
2. Meant for only point to point , any Analog transducer is placed at location only and only for physical concentrated.



1. Here within the Processor, there is ADC, so that data can be processed by Processor. likewise DAC is also a part of interface at Processor at MMI.
2. i.e wires carries only Analog signals.
3. TEDS.

Std. gives two options:

1. 4 wires option: 2 wires for Analog &
2 " " Digital. ~~comm~~ signal.

2. 2 " ": Same two wires used for both Analog & Digital ~~Comm~~ signal.

But Digital data/signal is superimposed to analog signals.

Note ① this std is used to accomodate earlier version / designed transducers.

② also used for long distance.

+ IEEE 1451.5 : Subtitle : "Wireless communication Protocols and TEDS Formats"

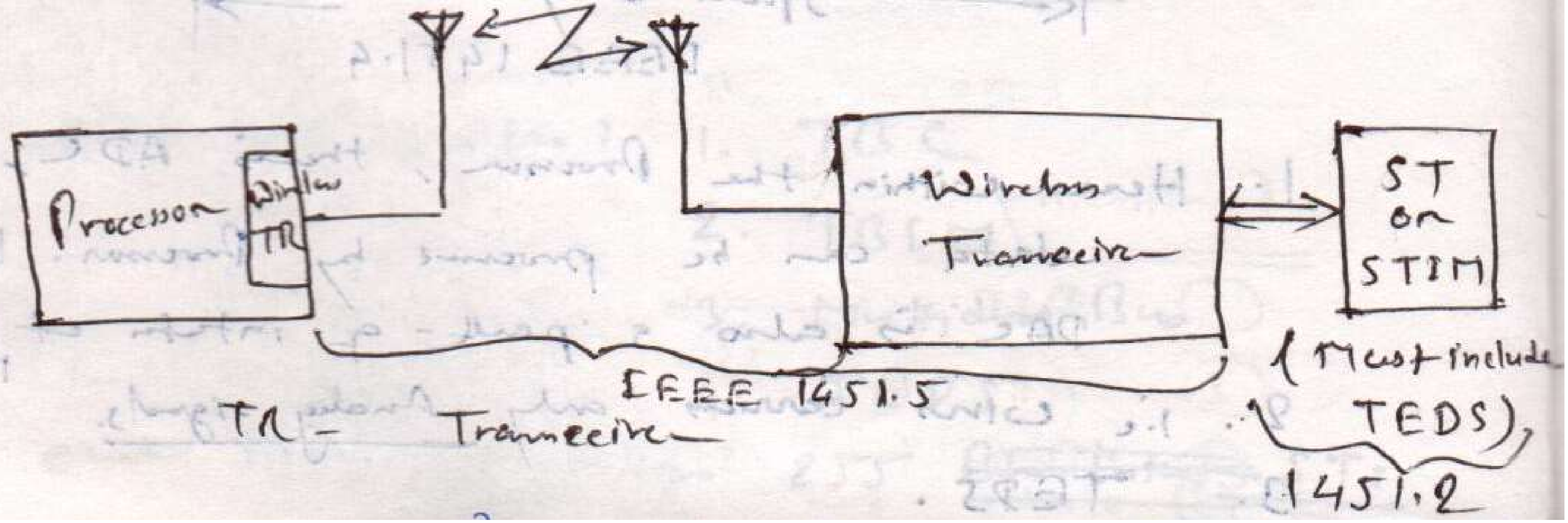
(IEEE 1451.5 - 2007)

It covers two things (~~scope~~):

i.e Scope

(a) Wireless transceiver for communication between S.T. & processor.

(b) TEDS

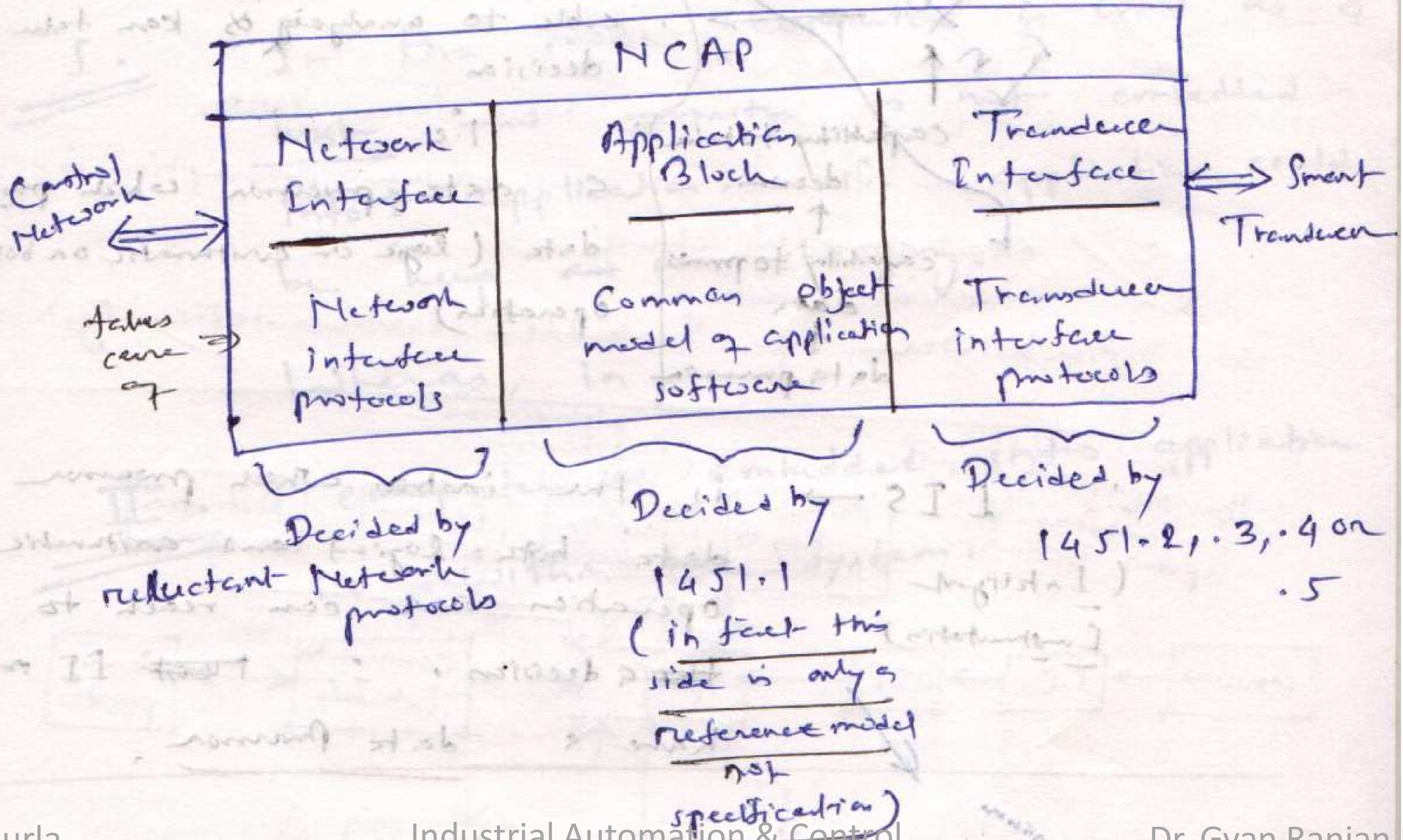


TR - Transceiver

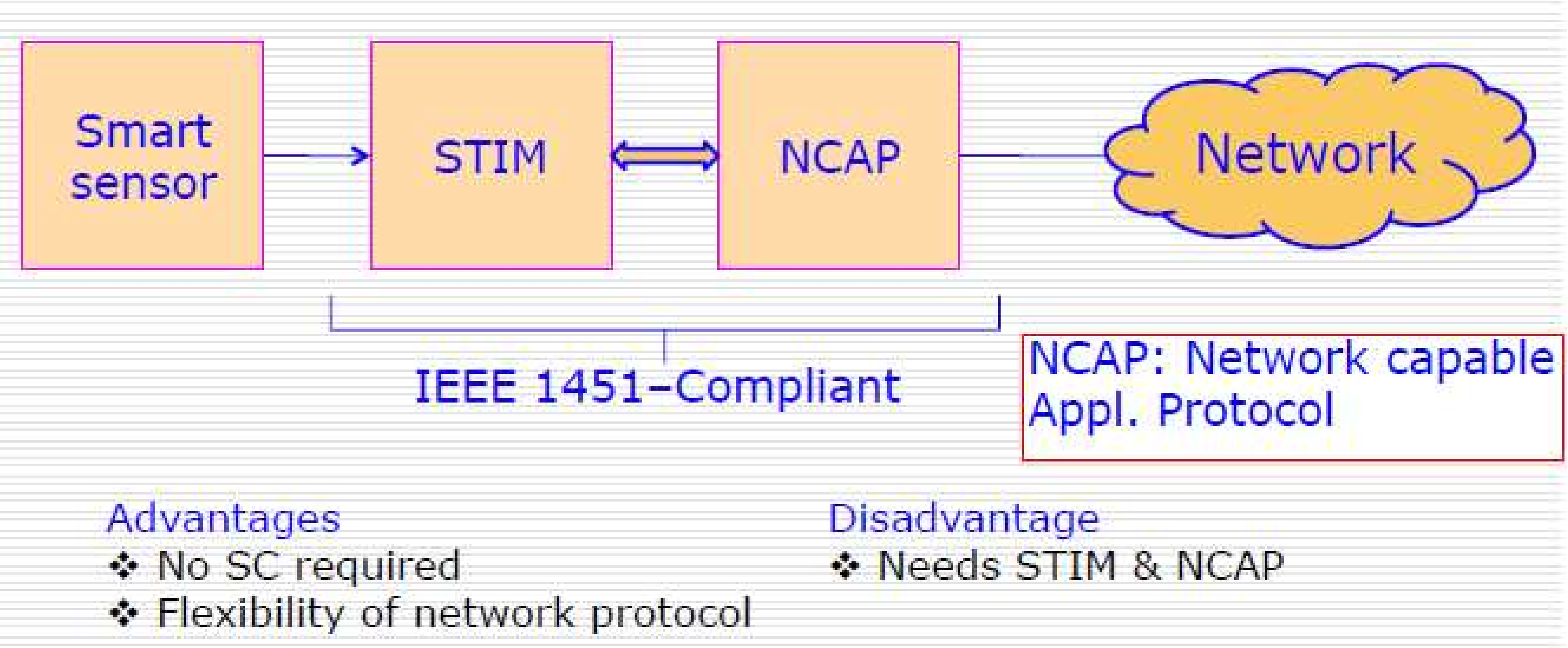
- IEEE 1451.6 : Subtitle : “High Speed CAN open –Based Transducer Network Interface for Intrinsically Sade and Non-Intrinsically Safe Application”

- IEEE 1451.7: Subtitle : “Transducers to Radio Frequency Identification (RFID) System Communication Protocols and TEDS Formats”

+ IEEE 1451.1 : Subtitle : " Network Capable Application Processor (NCAP) Information Model "



Smart Sensor + IEEE 1451 Interface



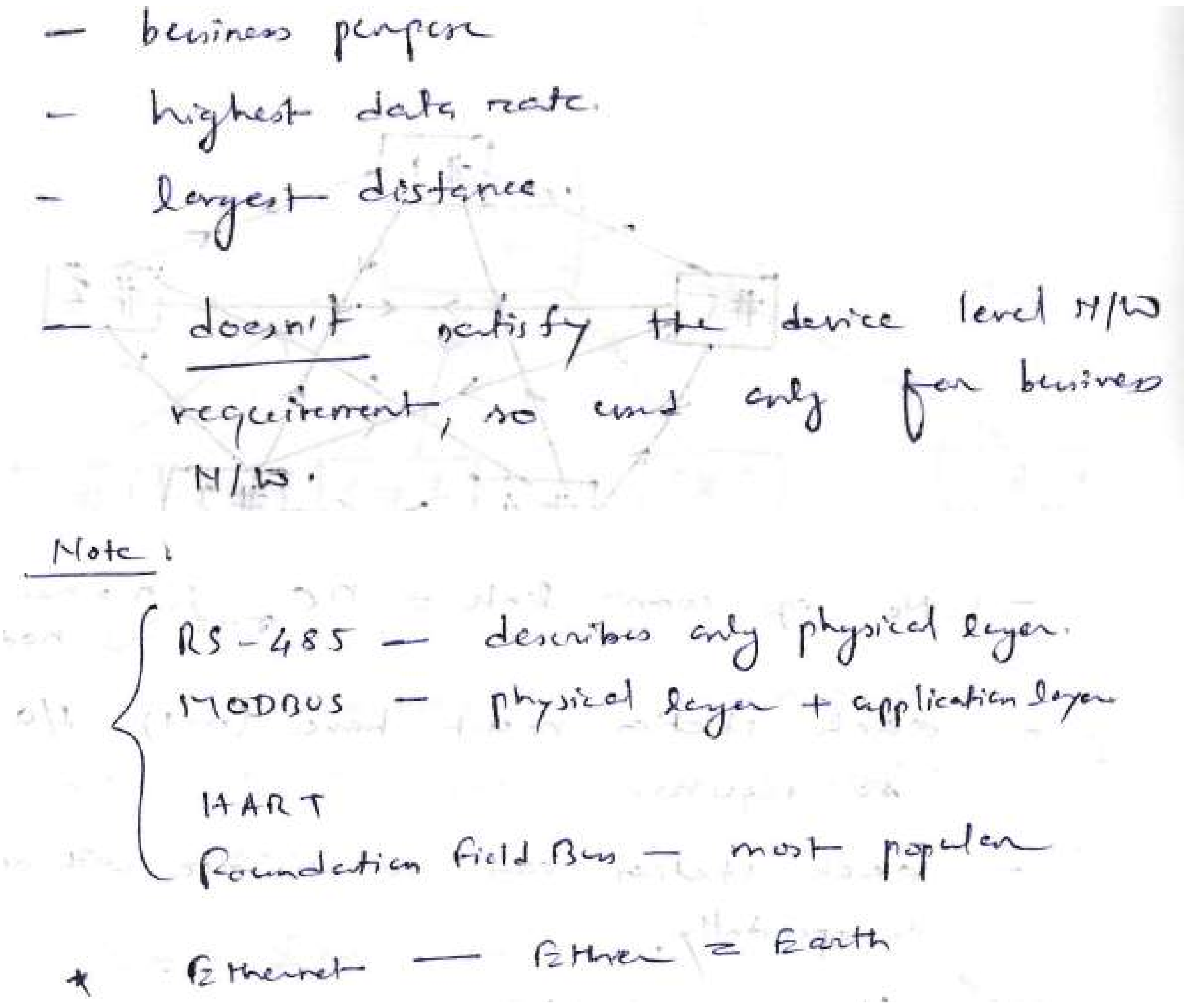
NCAP: Network capable Appl. Protocol

Advantages
- ❖ No SC required
- ❖ Flexibility of network protocol

Disadvantage
- ❖ Needs STIM & NCAP

Wired Network Protocols

Ethernet (IEEE 802.3)



- business purpose
- highest data rate.
- largest distance.
- doesn't satisfy the device level H/W requirement, so used only for business H/W.

Note :

RS-485 — describes only physical layer.

MODBUS — physical layer + application layer

HART

Foundation Field Bus — most popular

* Ethernet — Ether = Earth

1. Specifies two layer only

ⓐ physical layer } all 802 specifies these two only.
ⓑ data link layer

2a. Physical layer specifies 5 things:

(i) coding method.
  ↳ manchester coding

(ii) Transmission method
  ↳ Baseband transmission method

(iii) Transmission mode
  ↳ Half & Full duplex

(iv) Data rate

⟶

→ lowest rate : 10 MBps
Mid-1 rate: 100 Mbps
Mid-2 rate: 1 Gbps
Highest rate: 10 Gbps

(v) media : 5 commn media
→ co-axial, UTP, STP, MM fiber & SM fiber.

Ex:- . 10 - Base - 5 ← co-axial cable with charn impedance = 50 Ω

10 ← 10Mbps

Base ↓ Base technology

- 100 - Base - TX
  ↳ STP/UTP of category 5

  100Mbps ↗

  Higher the category
  ↕
  more is data rate.

- Baud rate = no. of changes
  - limited by ~~[illegible]~~ capacitance & ~~imp~~ inductance of the media.

- 1000 - Base - SX
  ↳ Multimode fiber
  S - stands for short distance
  = 275 meters

- 10G - Base - L
  ↳ SMF, L = Long distance
  = 10 km

2b. Data link layer

Two sub layer
a) MAC protocol
b) Data format.

MAC protocol, CSMA/CD

CSMA = Carrier Sense Multiple Access

CD = with collision Detection

- CSMA checks whether any signal is available on the link or not.

→ if not, then only transmit.

→ if present, then transmit after some random time.

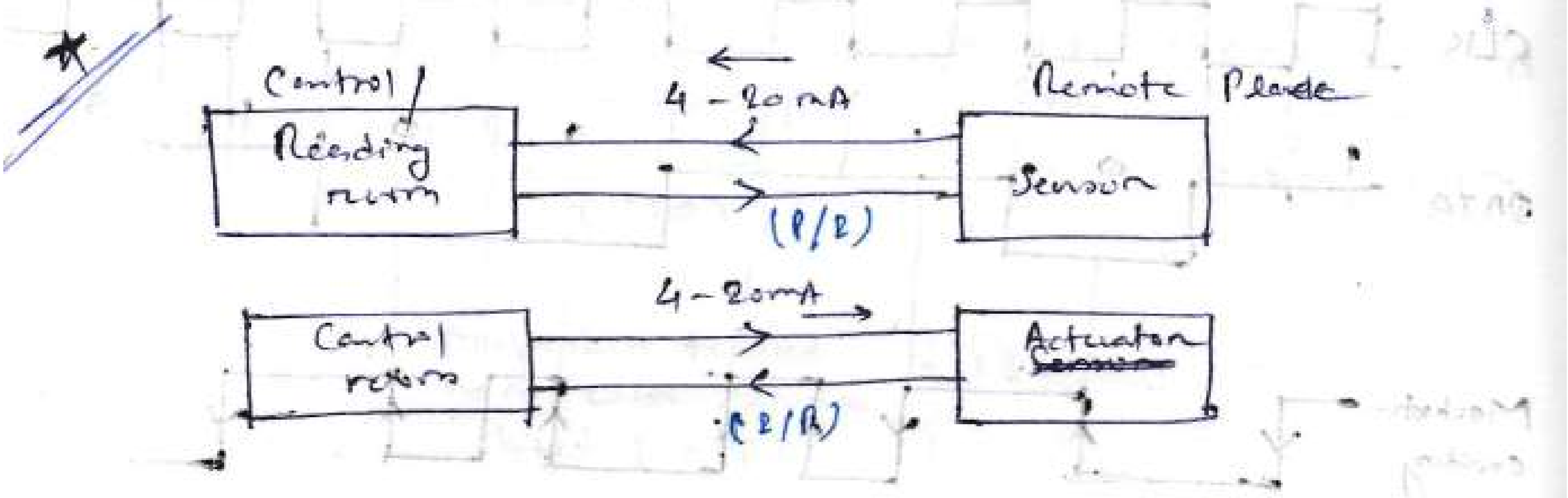
CMRR (common mode rejection ratio) = $\frac{A_{dm}}{A_{cm}}$

→ It may possible that the data may collide with other data as multiple users are using the medium.

→ So again. it withdraws the data from medium & returns. This will increase the delay.

HART

Highway Addressable Remote Transducer



meant for imposing 4 - 20 mA of signal on to digital signal.

- Digital comm^n in HART :

☆☆ Bell_202 FSK standard in digital comm^n has the following features:

- AC carrier of ±0.5 mA peak (1 mA pp)
- logical '1' : 1200 Hz carrier
- logical '0' : 2200 Hz carrier

Digital comm^n – Takes place in both the direction.

Analog comm^n – takes place only in one direction.

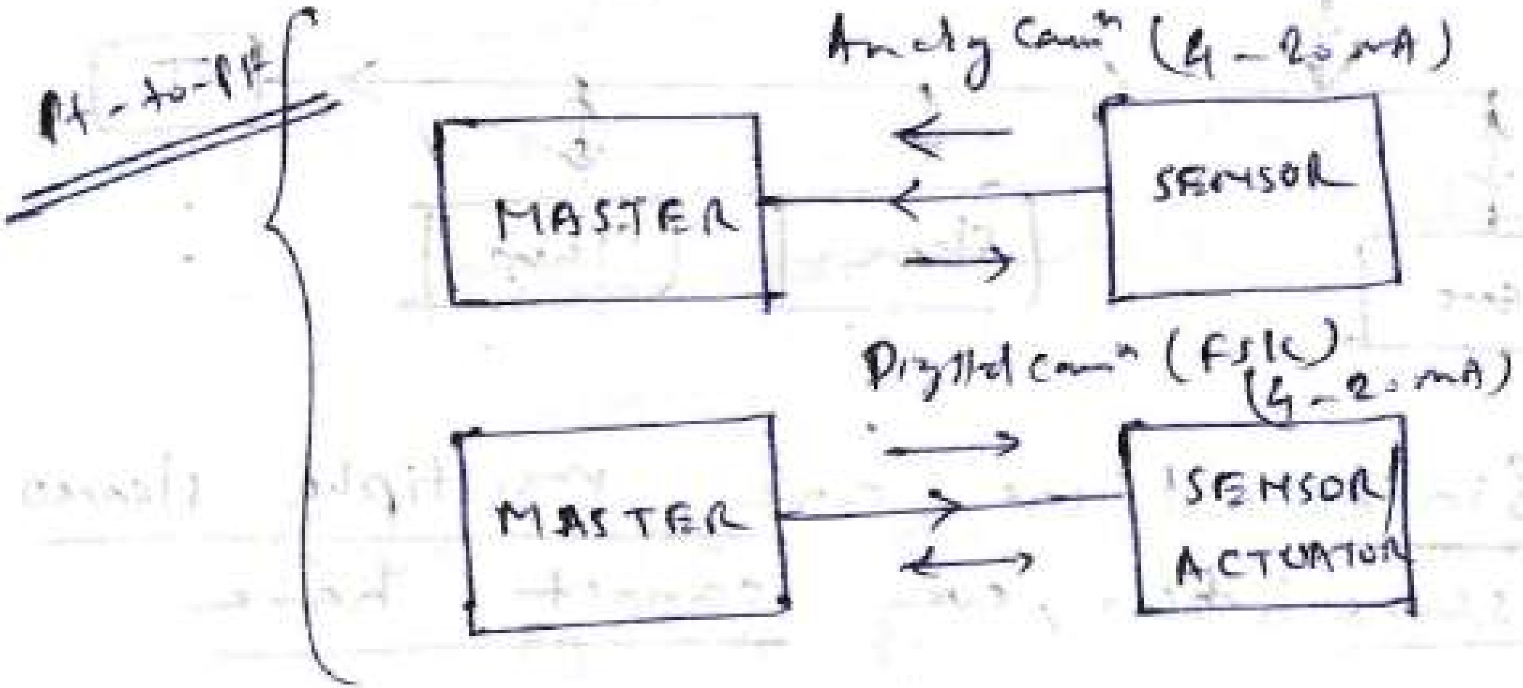
- Cable specification :

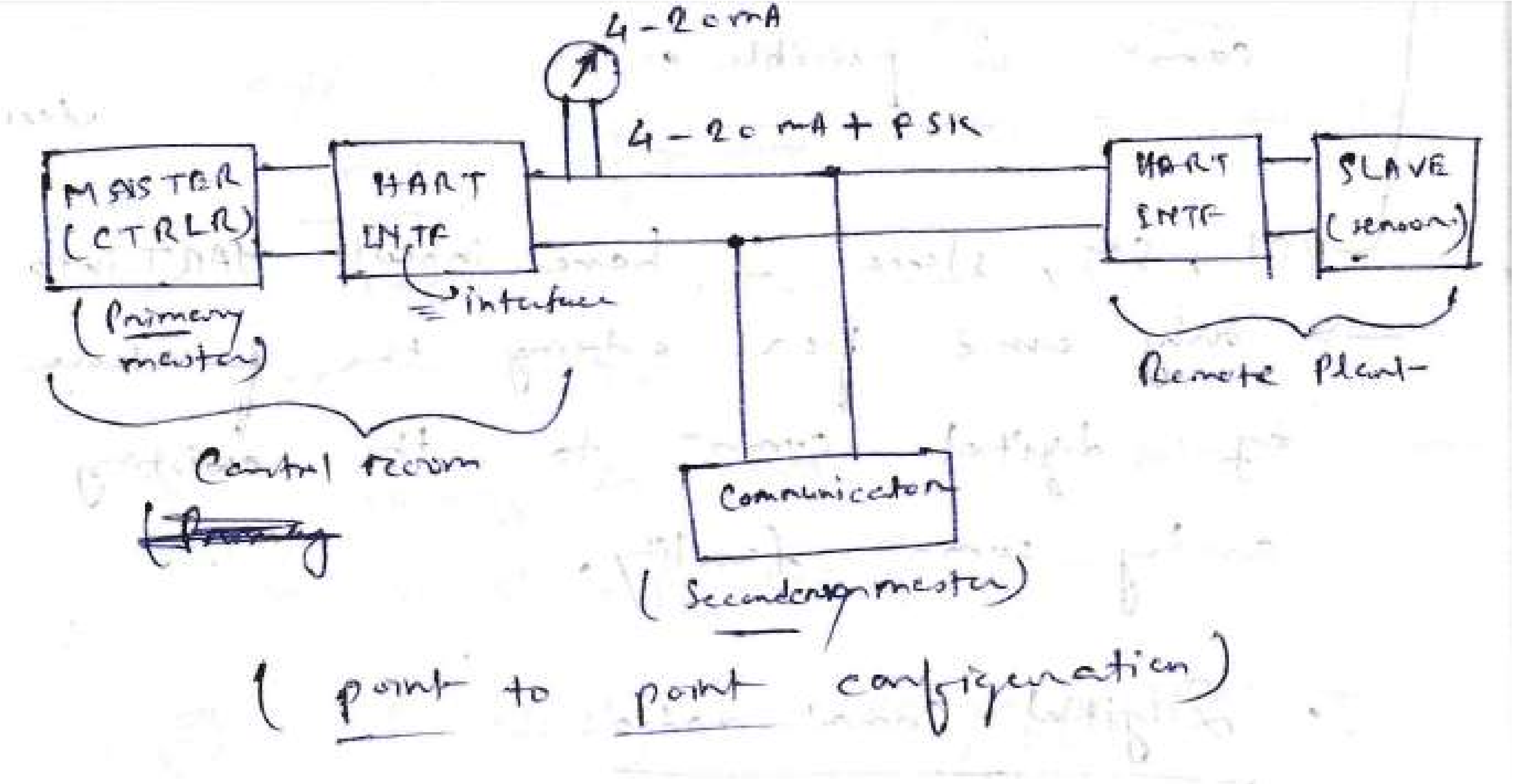
A. one UTP → allows max. cable length of 1.5 km

B. one STP → allows max. cable length of 3.0 km.

- Commn configuration or Topologies:
- Pt. - to - Pt. Comm V/S Multidrop or Party line configuration

- supports both analog & digital comm
- only digital comm is supported


Pt-to-Pt
Analog Commn (4-20 mA)
MASTER
SENSOR
Digital Commn (FSK) (4-20 mA)
MASTER
SENSOR
ACTUATOR


4-20mA
4-20 mA + FSK
MASTER (CTRLR)
HART INTF
interface
(Primary master)
Control room
HART INTF
SLAVE (sensor)
Remote Plant
Communicator
(Secondary master)
(point to point configuration)

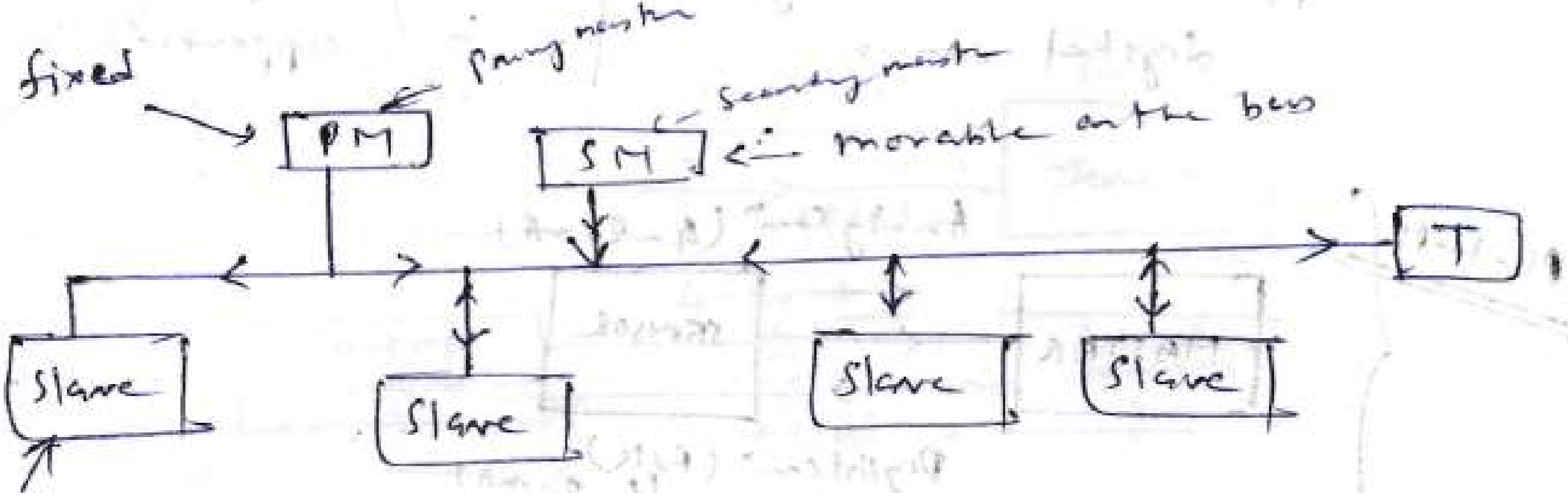
- Secondary master is used only for maintanance purpose which may be of mobile type.

PMMC – responds only to DC value of the signal

- analog comm^n : two dedicated wires.

- Multidrop or Partyline configuration

{ primary master + secondary master + no. of slaves on the bus.



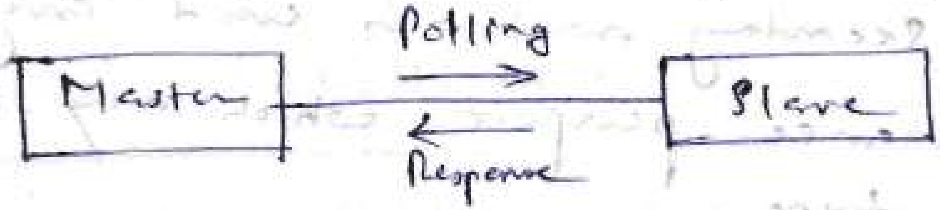
Since there are multiple slaves on the same bus, we cannot have analog commn. and hence only digital commn is possible.

→PM, SM, slave — have inbuilt HART interface

→ only used for adding the feature of digital commn to the existing analog commn facility.

- Digital Comm^n modes:

① Normal mode or poll-response mode



② Burst mode

{ one query followed by a burst of response.

- Limitations

① Applicable to 4-20 mA devices only.
② It allows single master only.

- Advantges

① Maintains 4-20 mA compatibility while allowing also digital commn.

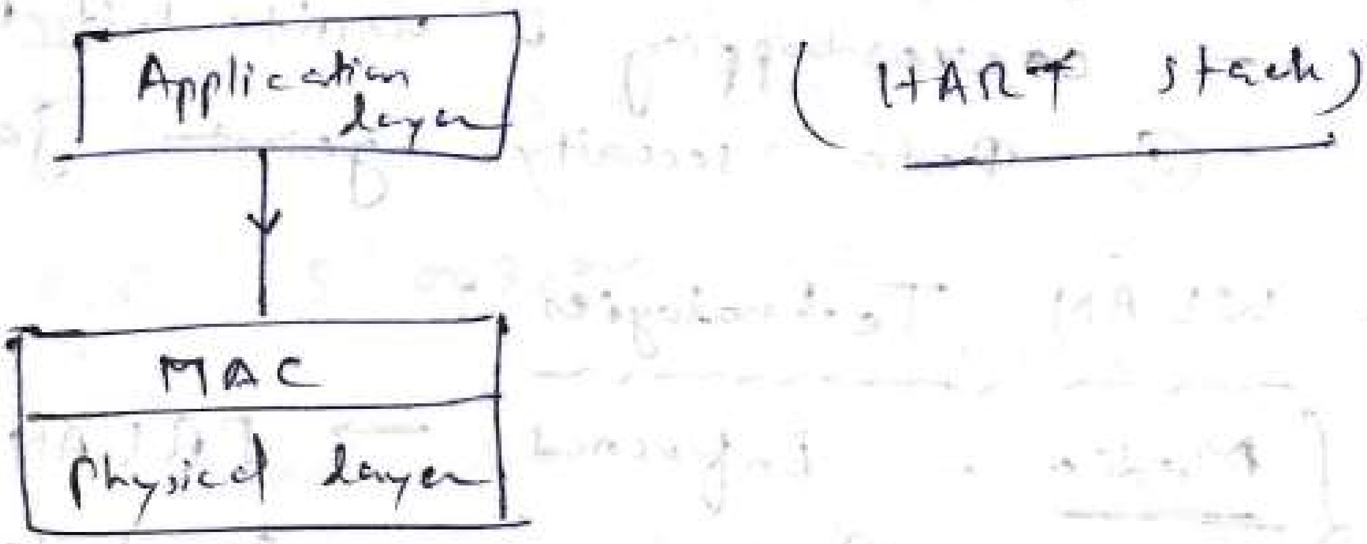
② No-risk solution as the compatibilites of 4-20 mA devices are not disturb.

③ Allows the device manufatures to add new features like remote reset, remote configuration, remote calibration.

④ HART devices can be added incrementally.

⑤ Saving in ~~cost~~ cabling cost because of multidrop configuration.

⑥ Relatively an easy protocol to understand & use.



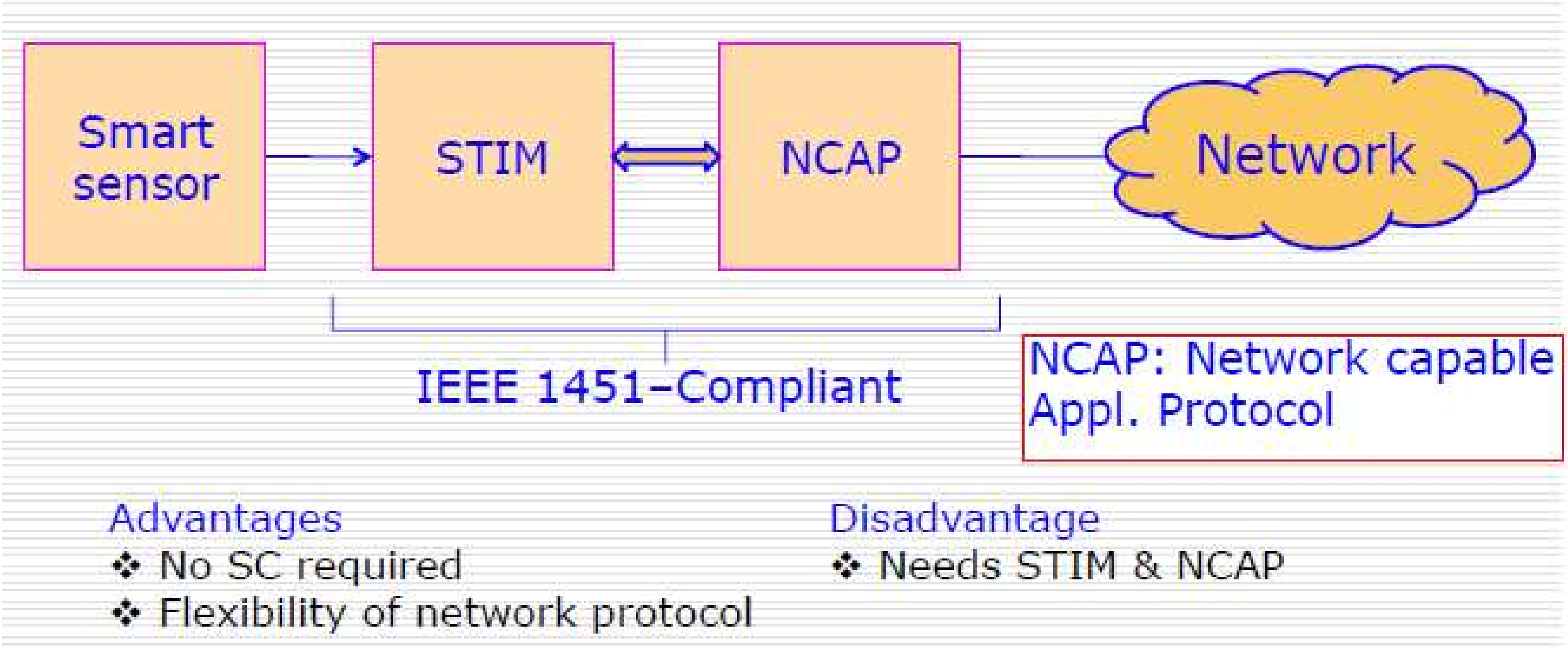
Thanking You

for

Your Patients Hearing

Email: gyanbiswal@gmail.com ; gyanbiswal@vssut.ac.in

Smart Sensor + IEEE 1451 Interface



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References

1. Nagender Kumar Suryadevara and Gyan Ranjan Biswal, "Smart Plugs: Paradigms and Applications in the Smart City-and-Smart Grid," *Energies, MDPI*, Vol. 12, No. 10, Art. 1957, pp. 01 – 20, May 2019. DOI: 10.3390/en12101957 {Invited paper}
2. Gyan Ranjan Biswal, Soumya Debasis Das, and Sourav Rout, "Smart Plug for Device-level Monitoring and Control," *Indian Patent Application No.*: 426/KOL/2020, Filing Date: Mar. 13, 2020.

- "Internet of Things Driven Speed Control of Electrical Equipment(s)", Amount: 50 thousand, Funding agency: NPIU-MHRD, TEQIP-III under Collaborative Research and Innovation (CRI) Scheme for Duration: 1 year from Jan. 2020 – Dec. 2020, Role: Principal Investigator (PI), (Ongoing). Vide. No. VSSUT/TEQIP/37/2020, dt. 16/01/2020

Introduction

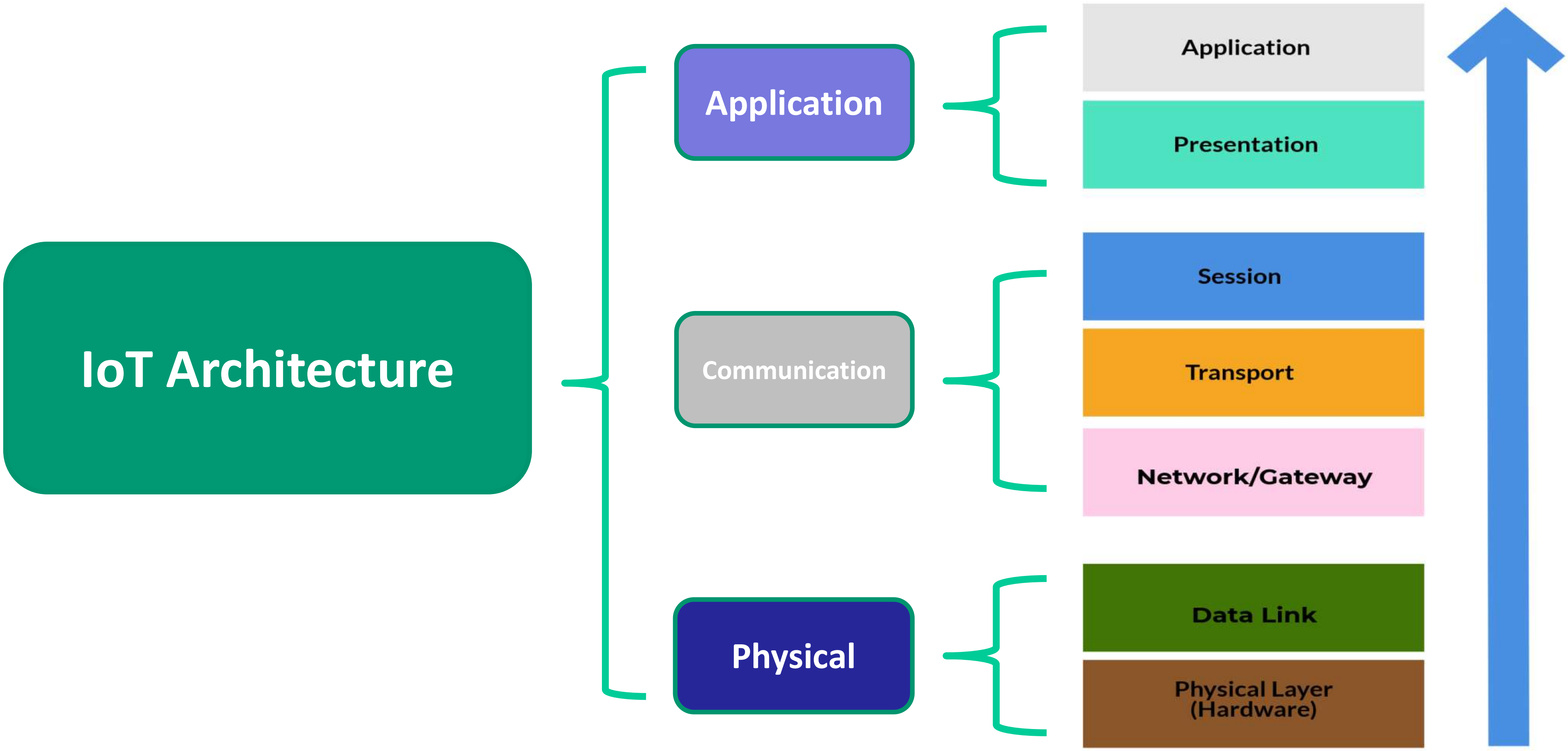
- Now-a-days, priority is always given to the renewable energy sources to fulfill our major stacks of power needs; immediate after the sources those generate the least carbon footprints, are considered at the second priority in the ladder of power generation.
- Roof-top mounted solar PV based distributed generation (DG) concepts are also gaining more and more popularity.
- DG concepts provide an opportunity to a consumer to convert themselves as the PROSUMER, that is, PROducing or generating power as well as CONSUMing the power as per their need and availability of surplus power.
- Now aforementioned concepts need highly complex and robust mechanism to implement at ground reality. Thus, we need a smarter electrical grid that can help us to make it possible, called “The Smart Grid”.
- *Communication Engineering* and *Information Technology* are the must to closely tied-up with conventional *Power Systems Engineering* to either establish a new Smart Grid OR to turn up a conventional grid into the Smart Grid.
- Realization and implementation of Internet-of-Things (IoT) is recognized as the ***cyber-physical system***. It is one of the most feasible but the most complex applications of IoT concept on ground reality.

What is Internet of Things?

- Internet + Things
- What is Internet?
  - Network of Networks
  - Each network is a collection of items
  - Each item has information
- What are the “Things”?
  - Any Physical object
  - Sensor and Actuators are embedded or attached
  - Has some measurable parameters

- Some examples:
  - IoT in Energy – Smart plug, Smart meters, Energy Management Systems
  - IoT in Industry – Predictive Maintenance
  - IoT in agriculture – Precision Agriculture
  - IoT for civil infrastructure – Structural Health Monitoring
  - IoT in Healthcare – Elderly Monitoring System

IoT System Architecture



IoT Architecture

Application

Communication

Physical

Application

Presentation

Session

Transport

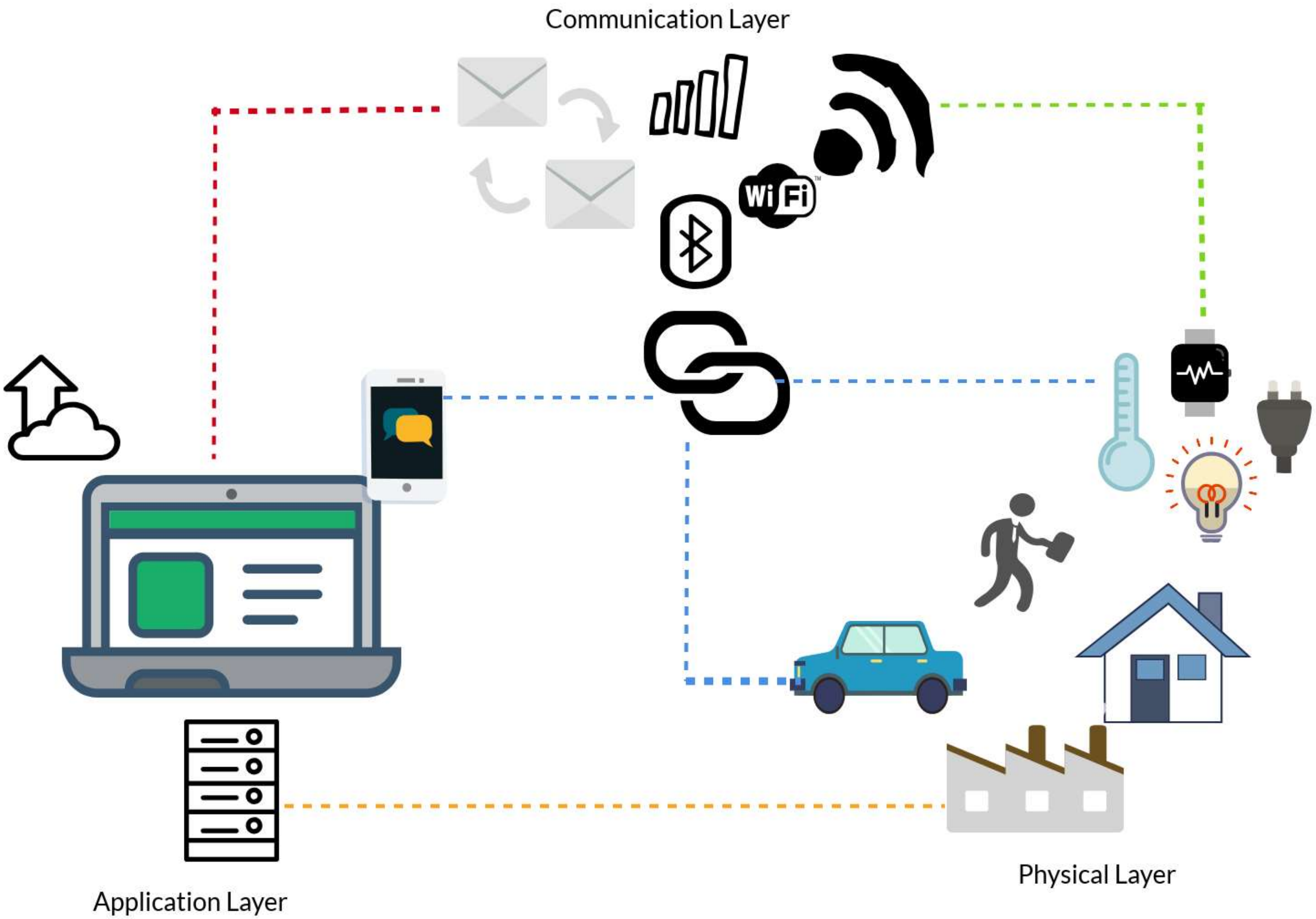
Network/Gateway

Data Link

Physical Layer
(Hardware)

IoT System Architecture

- Any IoT system consists of the following parts:
  - Physical Layer - Sensor and actuators with Embedded processing units
    - Sensors- Physical parameters to electrical
      - For example: Temperature sensors, Pressure sensor, Microphone
    - Actuators – Electrical signals to action
      - For example : Relay, Electronic flow valves, Speakers
    - Embedded processing units – To process the incoming electrical signal and to send out electrical signals
      - For example : Arduino , Node MCU, Raspberry Pi
  - Communication Layer
    - Channel for flow of data from one point to another
      - For example : Cellular Network
  - Application Layer - Data collection, Visualization and Analysis Architecture


Communication Layer
Wi Fi
Application Layer
Physical Layer

Components of an IoT enabled Sensors

- Sensor
  - Analog
  - Digital
  - MEMS/NEMS sensors
- Signal Conditioning Circuit
  - ADC
  - DAC
  - Instrumentation Amplifiers
- Microprocessor/Microcontroller
  - For local processing of sensor data
- Local Storage (optional)
- Communication support
  - For transmission of data to centralized gateway or directly to the internet

Benefits and Constraints

Benefits:

- Can operate as a standalone device in case of partial system/communication failure
- Real time collection and analysis of data
- Partially offload the computation load from the gateway and application layer enabling faster and accurate processing

Constraints:

- The system components need to be highly compact
- The power consumption of the sensor and the peripherals must be very low to enable continuous and efficient functioning
- Sensor placement, connectivity and fault tolerance need to be highly optimized

How to make IoT Environments Intelligent?

- Any IoT environment comprises scores of networked, resource-constrained and intensive, and embedded systems (digital objects, connected devices, and virtualized / containerized infra). The charter is to make them intelligent individually as well as collectively.

- The **Internet of Agents (IoA)** for empowering each digital object to be adaptive, articulate, reactive, and cognitive through mapping an software agent for each of the participating digital objects.

- The concept of **Digital Twin / virtual object** is also maturing and stabilizing.

- The proven and potential **IoT data analytics at edge/fog and cloud levels** is the prominent and dominant aspect for knowledge discovery and dissemination

- The application of **artificial intelligence (AI)** technologies (machine and deep learning algorithms, computer vision, natural language processing, video processing, etc.) leads to the realization of smarter systems, services and solutions.

IoT Realization Technologies

- The Realization technologies are maturing (Miniaturization, Instrumentation, Connectivity, remote programmability / service-enablement / APIs, sensing, vision, perception, analysis, knowledge-engineering, Decision-enablement, etc.)
- A flurry of edge technologies (sensors, stickers, specks, smart dust, codes, chips, controllers, LEDs, tags, actuators, etc.)
- Ultra-high bandwidth communication technologies (wired as well as wireless (4G, 5G, etc.))
- Low-cost, power and range communication standards: LoRa, LoRaWAN, NB-IoT, 802.11x Wi-Fi, Bluetooth Smart, ZigBee, Thread, NFC, 6LowPAN, Sigfox, Neul, etc.
- Powerful network topologies, Internet gateways, integration and orchestration frameworks, and transport protocols (MQTT, UPnP, CoAP, XMPP, REST, OPC, etc.) for communicating data and event messages.
- A variety of IoT application enablement platforms (AEPs) with application building, deployment and delivery, data and process integration, application performance management, security, orchestration, and messaging capabilities.
- Event Processing and Streaming Engines are for event message capture, ingestion, processing, etc.
- Edge / Fog Analytics through Edge Clouds.
- IoT Gateways, platforms, middleware solutions, databases, and applications on cloud environments.

IoT Connectivity Options

- **Multi-Sensor Fusion** – Heterogeneous, multifaceted, and distributed sensors talk to one another to create sensor mesh to solve complicated problems.

- **Sensor to Cloud (S2C) Integration** – Cyber Physical Systems (CPS) will emerge at the intersection of the physical and virtual / cyber worlds.

- **Device to Device (D2D) Integration** – With the device ecosystem is on the rise, the D2D integration is important.

- **Device to Enterprise (D2E) Integration** - In order to have remote and real-time monitoring, management, repair, and maintenance, and for enabling decision-support and expert systems, ground-level heterogeneous devices have to be synchronized with control-level enterprise packages such as ERP, SCM, CRM, KM etc.

- **Device to Cloud (D2C) Integration** - As most of the enterprise systems are moving to clouds, device to cloud (D2C) connectivity is gaining importance.

- **Cloud to Cloud (C2C) Integration** – Disparate, distributed and decentralised clouds are getting connected to provide better prospects.

- **Mobile Edge Computing (MEC), Cloudlets and Edge Cloud Formation** through the clustering of heterogeneous edge / fog devices.

The Smart Plugs

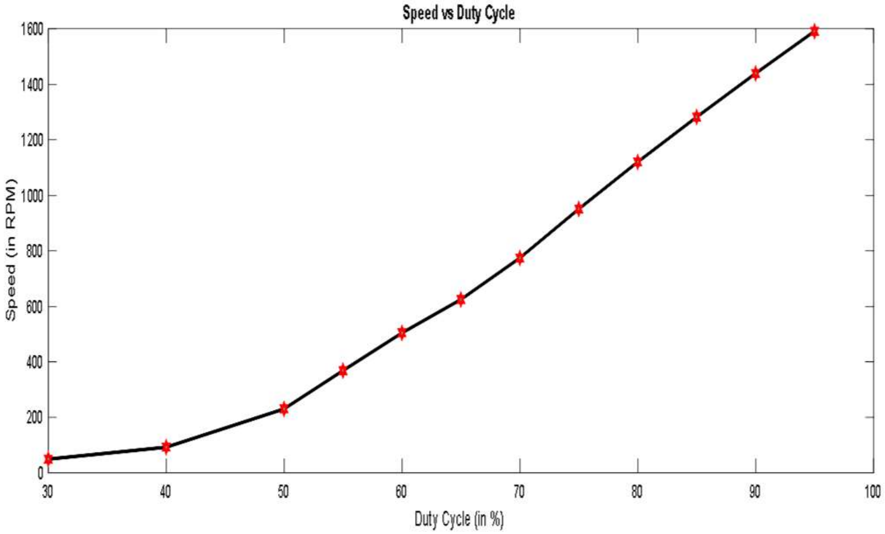
Gyan Ranjan Biswal and Soumya Debasis Das, “IoT Driven Smart Plug for Speed Control of High Current-rated Household Appliances,” *Indian Patent Application No.*: *202111011525 A*, Filing Date: Mar. 18, 2021; Publication Date: Apr. 09, 2021

IoT Driven Smart Plug for Speed Control of High Current-rated Household Appliances

- The invention relates to the design and development of a novel Smart Plug which is designed to remotely control the speed of high power-high current consuming electronic domestic appliances using low-cost communication protocol.

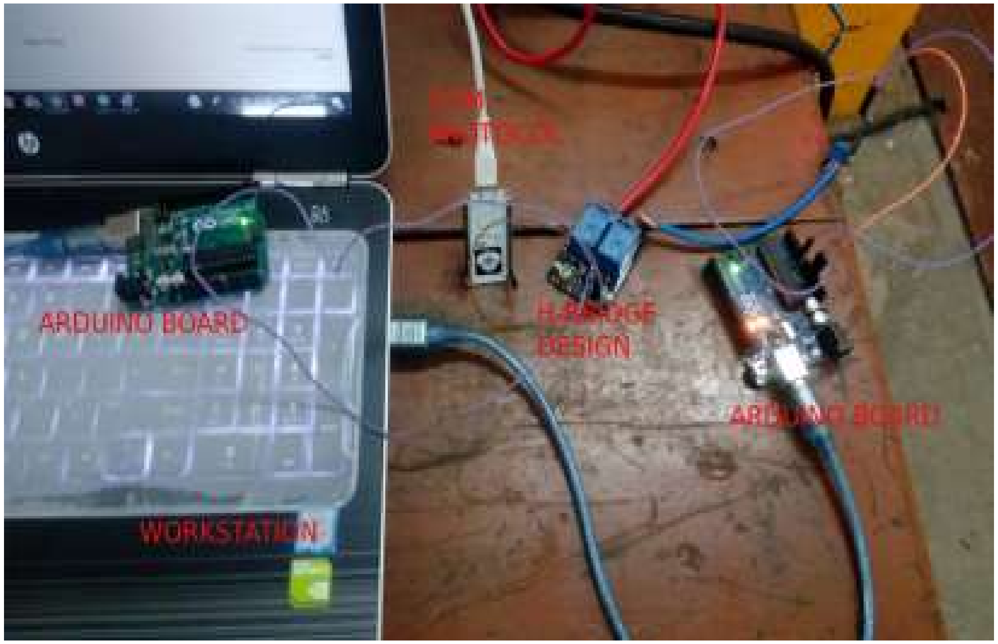
The main objective of the DC motor speed control using PWM is to take a signal representing the required speed, and to drive a motor at that speed.

- Pulse width modulation
- IGBT triggering sections
- DC power supply
- rectifier circuit through diode or thyristor
- Opto-coupler, Timer IC, and IGBT

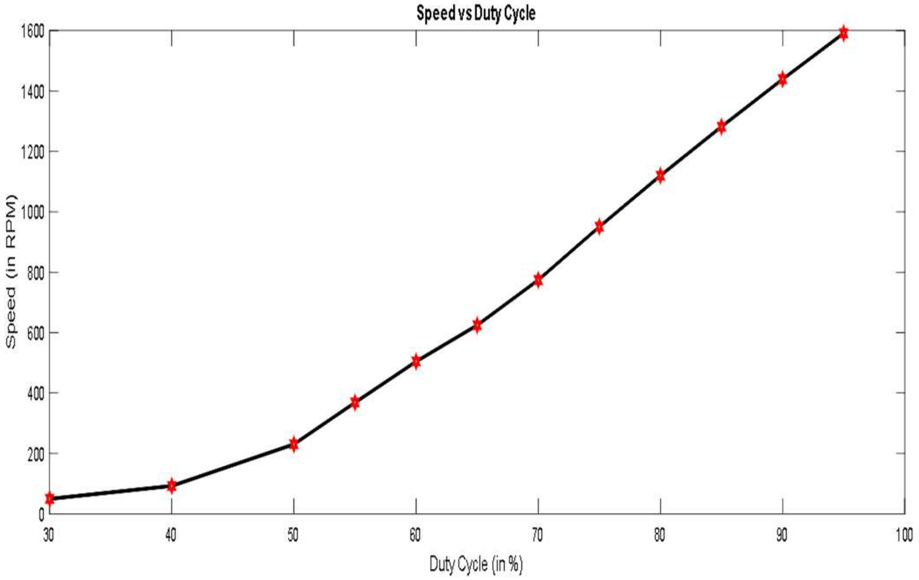


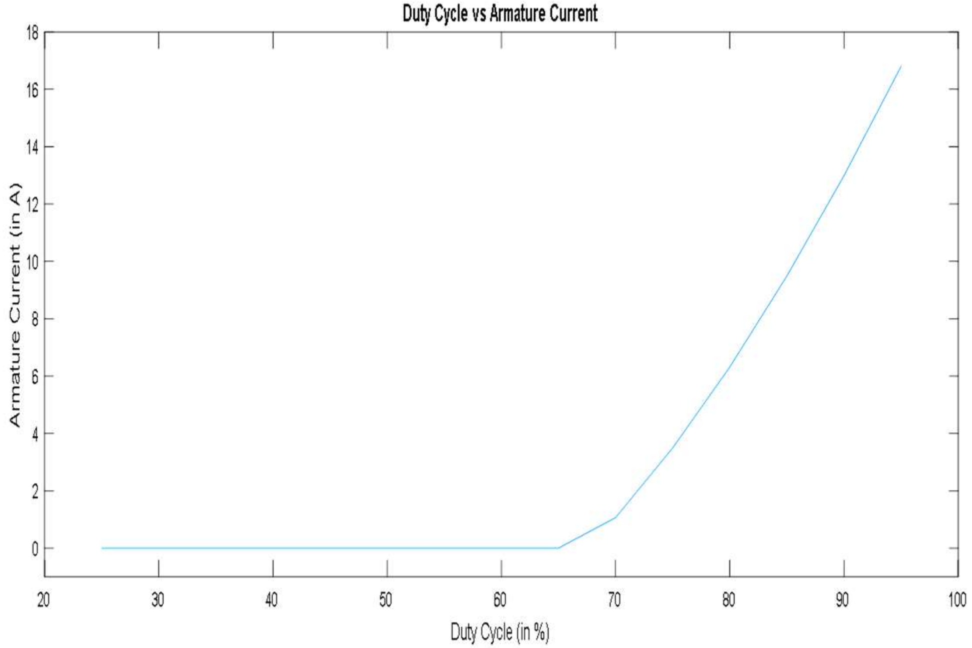
Speed vs Duty Cycle
Speed (in RPM)
1600
1400
1200
1000
800
600
400
200
0
30
40
50
60
70
80
90
100
Duty Cycle (in %)

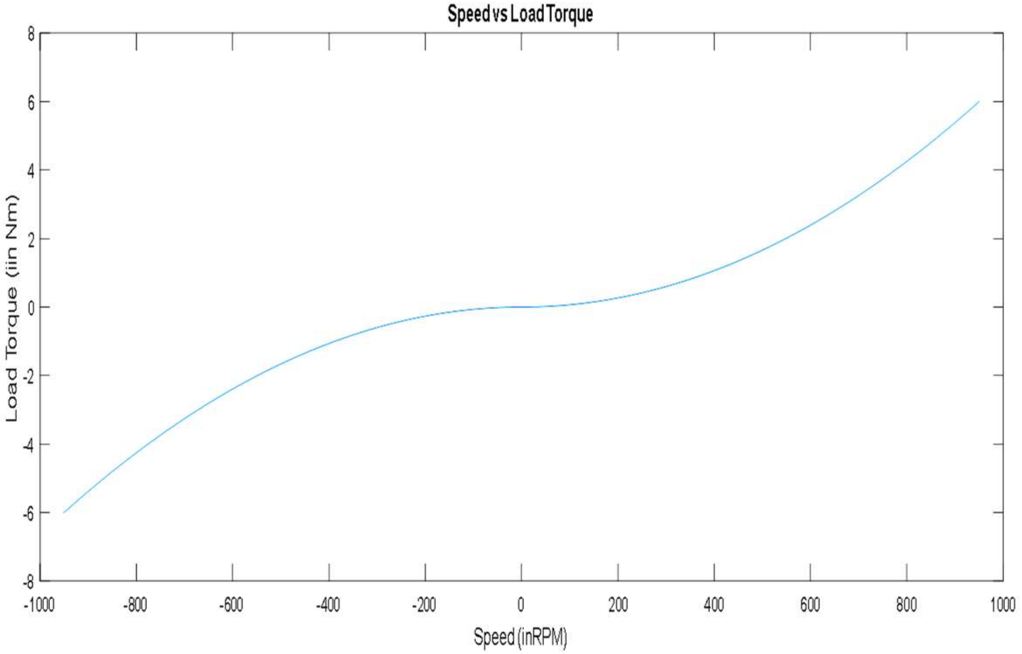
DC MOTOR SPEED CONTROL UNIT
ARDUINO BOARD



ARDUINO BOARD
H-BRIDGE DESIGN
ARDUINO BOARD
WORKSTATION


Speed vs Duty Cycle
Speed (in RPM)
1600
1400
1200
1000
800
600
400
200
0
30
40
50
60
70
80
90
100
Duty Cycle (in %)


Duty Cycle vs Armature Current
Armature Current (in A)
18
16
14
12
10
8
6
4
2
0
20
30
40
50
60
70
80
90
100
Duty Cycle (in %)


Speed vs Load Torque
Load Torque (iin Nm)
8
6
4
2
0
-2
-4
-6
-8
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
Speed (inRPM)

Current Research on IoT

IoT Network Design and Architecture

- IoT-enabled home networks
- IoT and SMART cities

Context-awareness and Location-awareness

Self adaptive services

- Context-aware models and protocols
- Context-aware services - transportation system, buildings, roads, water supply, environment and healthcare.
- Energy-efficient networks

IoT Services and Applications

Architectures of IoT services

- Tools and technologies for IoT services
- Energy optimization in IoT
- Modeling and simulation of IoT applications

Current Research on IoT

SMART Environment

- Smart cloud and IoT
- Smart homes and cities
- Adaptive user interfaces for smart applications
- Interconnection of smart devices (things)
- Dynamic urban communications
- Indoor communications
- SMART healthcare and assisted living
- SMART transportation and vehicles
- MART phones applications and services

Current Research on IoT

Energy Efficiency

- Energy efficient service provisioning
- Energy efficient resource utilization
- Data storage and processing
- Energy-efficient networking
- SMART devices and tools
- Energy metrics and benchmarks
- Energy-aware hardware.

Thank you