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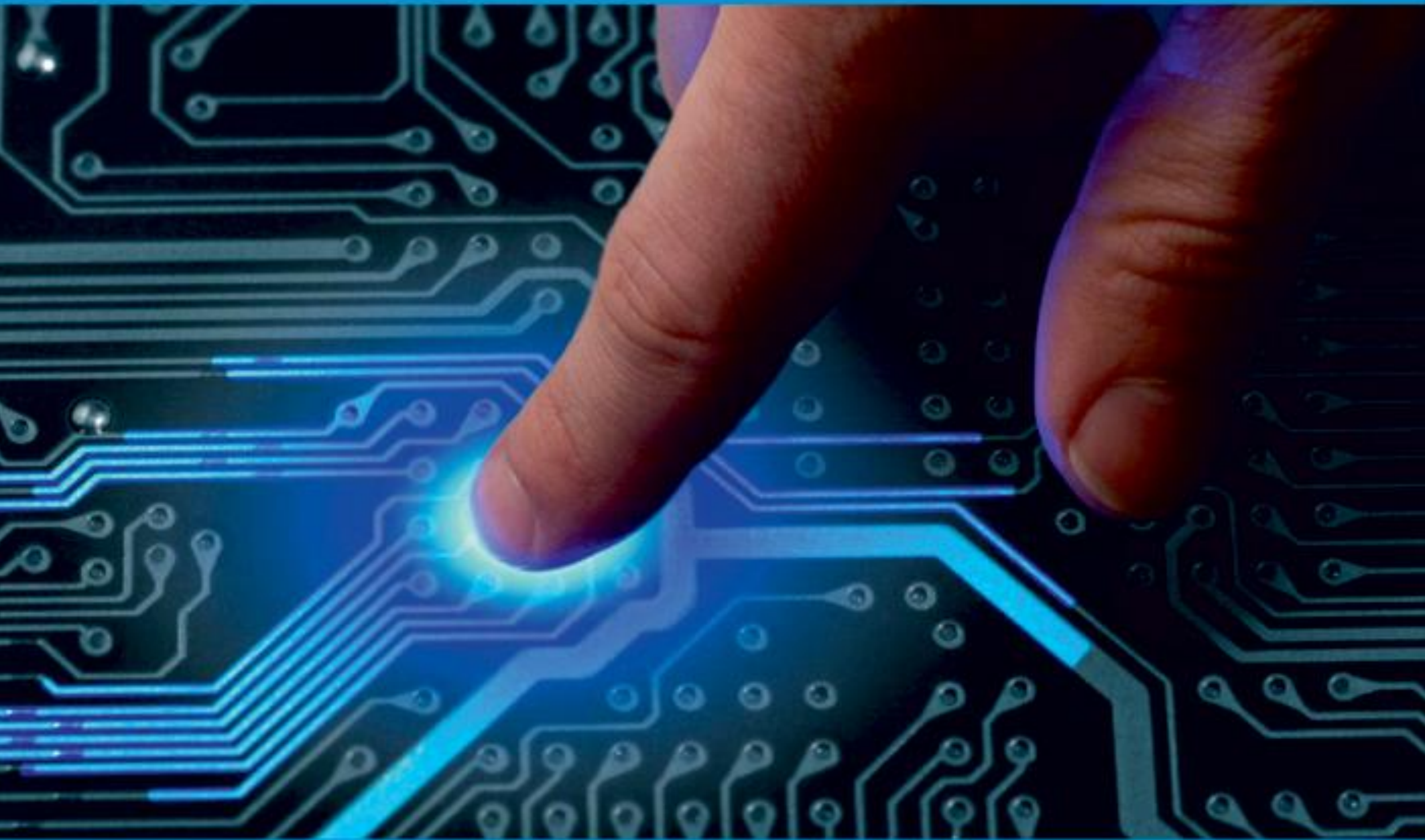

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QOS in Wireless Sensor Network-Fault Tolerance and Efficient Bandwidth Allocation

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ABSTRACT: Wireless sensor networks are an integral part of Industrial Revolution 4.0. The traffic efficiency of any network depends on link failures and available bandwidth. This paper discusses route discovery in case of a link failure and a control system approach for efficient bandwidth allocation. Control system approach has been attempted to address the twin issues of link failure and bandwidth allocation.

The main function of Wireless networks is to gather information about various types of parameters, notably process variables in industries, air quality variables in ambient air monitoring, weather forecasting, cyclonic alertness, congestion and other parameters in traffic routing. The outputs from WSN are feed into Plant systems either to display or control the variables. Naturally for efficient, reliable display and control of parameters continuous supply of information from WSN to Plant systems is important. Hence improving Quality of Service Parameters like signal to noise ratio, fault tolerance, Band width allocation, and stability and load balancing is vital while designing a WSN. We discuss about two QOS parameters in WSN namely Fault Tolerance in case of Link failures and Efficient Bandwidth Allocation. Links here are wireless in nature.

KEYWORDS: Wireless Sensor Network (WSN), Proportional Integral Controller (PID), Programmable Logic Controller (PLC), Distributed Control Systems (DCS), Data Acquisition System (DAS), Quality Of service (QOS).

I. INTRODUCTION

Computerization and automation in industry has led to digitization of manufacturing industries [1]. Advanced machine learning, data mining, Internet of things, wireless sensor networks, artificial intelligence, self organizing and learning networks, ERP, cloud computing are many facets of Industry 4.0.Most significant factor is availability of real time data which is reliable, accurate and precise. The term Industry 4.0 is synthesis of advanced manufacturing techniques and the Internet of Things to create intelligent manufacturing systems. When we say intelligent it means they are interconnected, communicate, analyse and feedback information (intelligence) into decision support systems and physical components. The main function of Wireless networks is to gather information about various types of parameters, notably process variables in industries, air quality variables in ambient air monitoring, weather forecasting, cyclonic alertness, congestion and other parameters in traffic routing. The output from WSN is feed into Plant systems either to display or control the variables. Naturally for efficient, reliable display and control of parameters continuous supply of information from WSN to Plant systems is important. Hence improving Quality of Service Parameters like signal to noise ratio, fault tolerance, Band width allocation, and stability and load balancing is vital while designing a WSN.We discuss about two QOS parameters in WSN namely Fault Tolerance in case of Link failures and Efficient Bandwidth Allocation. Links here are wireless in nature.

II. RELATED WORK

Industry 4.0 offers a revolutionary paradigm shift where in subjectivity of human nature in decision making could be completely eliminated. The term Industry 4.0 is synthesis of advanced Manufacturing techniques and the Internet of Things to create intelligent manufacturing systems. Many manufacturing process have optimized process parameters increasing yield, recurring periodic defects were being identified, material moving machineries organized in an optimized way in logistic terminals and ports depending on likely arrival of materials.(nature and quantity Foundations of Industry 4.0.Wireless sensors are basic components of Internet of Things (IoT) and Industry 4.0. IOT connects sensors and hence data from them to decision making systems via cloud [2]. Raw data from these are gathered,

analyzed, patterns recognized and automated, objective decisions are taken ideally without human intervention. Needless to say the efficacy of decision system depends on accuracy and reliability of sensors and hence their data.
SCADA,PLC,DCS are typical control systems used in manufacturing Industry. controlling the output. (Dunn Thomas 2015)SCADA system is a PC/Computer installed with software to access process data from field and displays the required parameters on Human Machine Interface (HMI). control valves, motors, pumps, display devices .A PLC consists of processor or central processing unit (CPU), rack or mounting panel, Input cards, output cards, power supply and programming unit, device, or PC/software. As plants spread over a geographical area bringing all signals into a single PLC housed in a Master Control Room (MCR) and sending outputs again to field will increase cabling cost and maintenance cost. These limitations of PLC are addressed in DCS. Distributed Control System is a Network of Interconnected devices including number of PLC's and SCADA)[3], Whereas PLC are used to control the particular operation in a plant but DCS is used to control the entire Plant. In a DCS the entire plant level logic and hardware is distributed into different subsystems each either controlled by PLCs or monitored by a SCADA.(depending on requirement).These separate subsystems are in turn linked to each other and can be monitored by a HMI/SCADA/interface at MCR .

III. PROPOSED ALGORITHM

A. FAULT TOLERANCE IN WSNs:

High noise, low signal to noise ratio, obstacles, multi path fading and interference, electromagnetic noise generated by pumps, motors, turbines, affect the quality and reliability of date transmitted from sensors over a wireless link. Actuators1, Link failure (hence data loss) is common whenever there is an interference form same frequency noise sources [2].
Network Protocols and Algorithms: A PLANT SYSTEM performs many operations and tasks. First step here is for PLANT SYSTEM to scan all the input devices. Then a corresponding memory table is updated. Then algorithms or ladder logic is executed. Based on the outcome of this execution an output memory table is updated. This output memory table decides the state of final control elements like a valve to be open or close, a pump is to be start or stop. This whole time is called scanning time of a PLANT SYSTEM.
Hence scan time is the time taken by PLANT SYSTEM to read inputs, execute program and as per input/logic update outputs accordingly. Scan time is mostly in milliseconds, from 2ms on words. The scan time controller depicted in Fig.1.

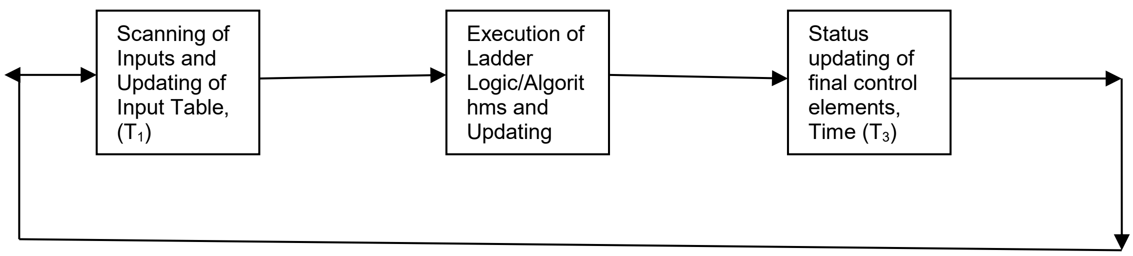

FIGURE 1: Scan time of a Control system.

The following equations (Eq.1) represent the scan time.

Scan time Ts = Time required for completing above one cycle

$$Ts = T1 + T2 + T3 \quad \text{Eq.1}$$

Typical values from 1 milliseconds to 1000 milliseconds.

PLANT SYSTEM: Scan time depends on no. of inputs, outputs and program size (total memory used).Hence scan time is different for different programs within a PLANT SYSTEM. Less scan time means faster PLC action. Normally

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DCS scan time are 200msec, 500msec,1 sec PLC scan time are less than 100msec. Further tasks may be cyclic and periodic.

CYCLIC execution: Processes inputs, solves logic program, processes outputs, same thing on the next scan. Sequences the task cycles, one after another. After outputs are updated, the system performs its own specific processing then starts another scan, without pausing. The cycle is checked by the watchdog timer.

PERIODIC execution: Here one can define total maximum time required for processing of inputs, algorithm execution and updating of outputs. The defined period may be in the range of 1 to 255 ms.

Fault Tolerance: Sensors transmit signals to Data acquisition, stand alone PID controllers, remote Input /output and PLC systems or in DCS systems (here in after referred as plant systems) over wireless links.

Fault tolerance is applicable in two configurations:

1. Single WSN in local wired loop connected to Plant Systems
2. Single WSN connected to Plant Systems through base stations
3. A group of WSNs in mesh configuration connected to Plant Systems by a single base station
4. A group of WSNs connected to Plant Systems connected to Plant Systems by dedicated Base stations for each constituent WSN.

Plant systems scan signals from individual sensors of WSN cyclically in a predefined interval. This elapsed interval from the time last sample taken and to present sample time is called scanning time. Plant systems have a scan period of 20ms i.e. in one minute a plant system can scan at most 50 signals assuming equal scanning period for all sensor signals. The number of signals scanned can be increased either by increasing the scanning period(degreasing the scanning rate/sample rate) or by a differentiated scanning period for different sensor signals depending on criticality .If say temperature is a critical in a particular WSN the it will be given a smaller scanning period (hence more scanning rate)compared to other signals. Other signals will be scanned at a lower sample rate or with more scanning interval.

We explore this differentiated scanning period for compensating failure in a single or more than one wireless links. Further it is assumed that sensors in a particular unit/smaller geographical are wired. Since the distance between such sensors is small wiring costs are minimal. This wiring cost can further be reduced by using spanning tree wiring /partial spanning tree wiring as this backup is only needed in case of link failures.

Let S1, S2, S3, Sn be sensors in a particular WSN with a scanning periods of P1, P2, P3, P4

Pn with P1, = P2> P3, P4. Suppose there is a wireless link failure between S2 and base station/Plant systems. Then S2 searches for a sensor which has a scanning period more than it. Now signals from S2 are routed through either S3 or S4 depending on chances of earliest arrival of S2 signal to base system /Plant systems .Note that S1, S2, S3,………. Sn is wired.

Further route discovery can be optimized so as to make traversal time of sensor signal from, S2 through P3 or P4 optimal/minimum. As sensor transmits signals continuously and most sensor signals are analog any partial loss of sensor signals to Plant System does not jeopardize the process control. Most sensor signal transmission rates are far more than scanning period of Plant systems. Same concept can be extended to a group of WSNs with their dedicated base stations connected as tree or mesh formation.. Here when a link failure between a particular base station and plant system occurs signals from critical but failed link BS are routed to other base stations.

Consider a reactor system with 6 measurement parameters. Obviously temperature and pressure are given high priority. Normally conductivity and density of a fluid does not change drastically and quickly. Hence they are assigned lesser priorities. When there is a link failure between temperature sensor and plant system, signals are routed to Plant system vi conductivity sensor o/p port and density sensor output port. Same has been depicted in Table 1 and Table 2.

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Parameter	Priority	Unit
Temperature of reactor	1	Deg C
Pressure of reactor	2	Kg/cm2
Flow of coolant/fuel	3	lpm
Level of fluid in reactor	4	%
Density of coolant/fuel	5	kg/cm3
Conductivity of coolant/fuel	6	µS

TABLE 1: Priority table of different process parameter

Sensors	Sample at T_1	Sample at T_2	Sample at T_3
S_1	1.3 kg/cm3		450 Deg C
S_2	450 Deg C	…….	
S_3	34 lpm		
S_4	2.3 Kg/cm2		
S_5	14.5 %		
S_6	200 µS	450 Deg C	

TABLE 2: Sample access mechanisms

B. FAIR EFFICIENT BW ALLOCATION SCHEME USING PID CONTROL ALGORITHM – A CONTROL SYSTEM APPROACH

As stated earlier Plant Systems scan sensor signals according to criticality We are considering Bandwidth allocation (hence scanning rate) at Plant Systems level. We will be extending same principles to Bandwidth allocation at Base station levels in our future studies. Each Plant system sets its cycle time so as to full fill the minimum requirements of all Sensors /WSNs under it. The Plant system allocates BW to the WSNs as follows: Each base station /WSN sends the information about above three categories of queues. Plant system calculates BW to be allotted for these priority queues per BS using our fairness allocation algorithm

In Process Control Instrumentation we use Proportional Integral Derivative (PID) Controllers for controlling the process variables. Here we extend the concept of Process regulation to Bandwidth allocation. We consider Plant system as controlling station and controlled station is BS (WSNs/Sensors as the case may be). At field BS is controlling station and WSNs/Individual sensors are controlled station. BW allocation is cyclical and done by polling. PLANT SYSTEM allocates BW to BSs and they in turn allocate the BW by ascertaining the BW requirements by polling. So the allocation has to dynamically change. Bandwidth allocation is a two stage process at PLANT SYSTEM, BS levels. We are considering Bandwidth allocation at PLANT SYSTEM level. We will be extending same principles to Bandwidth allocation at BS levels in our future studies.

Each PLANT SYSTEM sets its cycle time so as to full fill the minimum frame size of all base stations. The Proportional-Integral-Derivative (PID) Controllers Consist of three basic modes, the Proportional mode, the Integral and the Derivative modes.

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A Proportional algorithm

The proportional mode adjusts the output signal in direct proportion to the controller input (which is the error signal, e). The related parameter is called the controller gain, kc.

. The larger kc the more the controller output will change for a given error. E.g. Controller o/p = Gain X error. A proportional controller reduces error but does not eliminate it

There will be an offset between the actual and desired value.

A proportional integral algorithm

To reduce offset we introduce integral mode or reset action. It corrects for any offset (error) that may occur between the desired value (set point) and the process output .The tuning parameter here is integral time (Ti) of the controller.

Reset is the time it takes for the integral action to produce the same change in MV as is the P modes initial (static) change.

A Proportional Integral Derivative algorithm

Derivative action (also called rate or pre-act) anticipates the direction of process. TD is the ‘rate time’ and this characterizes the derivative action (With units of minutes). The derivative action improves Dynamic response . Derivative action depends on the slope of the error, unlike P and me. If the error is constant derivative action has no effect.

Controller tuning involves the selection of the best values of kc, Ti and TD. It depends on the characteristics of the processes. Many methods of tuning are there. Viz. Ziegler Nichols closed loop method, Cohen – Coon, Direct synthesis. In PID control following are the terms to be associated.

$$MV = K (e1) + 1/Ti \int (e2) + Td\, d/dt\, (e3) \quad \text{Eq.2}$$

Where K= Proportional gain, Ti= Integral Time Constant, Td= Derivative time constant

The Algorithms:

Standard PID Algorithm:

Output = Proportional Constant {e(t) + (∫e(t)dt/I) +D de(t)/dt}

Kc, Kp are gain; I, Ip are integral and D, Dp are derivative settings. (Ogata Katsuhiko 2009)

PID Program:

Here is a simple software loop that implements a PID algorithm:

```
previous_error = 0
integral = 0
start:
error = set point - measured_ value
integral = integral + error*dt
derivative = (error - previous_ error)/dt
output = Kp*error + Ki*integral + Kd*derivative
previous_ error = error
wait(dt)
goto start
```

We see a similarity between BW allocation process and normal process control processes.

Amount of data to be transmitted: As this amount is more we will give a larger proportionality constant to our PID controller implying more control action and more BW allocation.

Amount of Bandwidth mismatch in previous cycles: As this amount is more we will repeat the control process more i.e. integral time constant is smaller.ie, more numbers of control action frequently.

Priority queuing is done by increasing derivative action. i.e. slope gets increased.

Let BWa be BW allocated earlier and BWd be BW required in the present cycle. So the error is e1= BWa- BWd

Let BW di be BW demanded at instant ‘i’ and BWai be BW allocated at instant ‘i’. Let BW dii be BW demanded at instant ‘ii’ and BWaii be BW allocated at instant ‘ii’. If there is consistent mismatch beyond expected degree in previous 2 intervals then we will decrease the Integral Time so that more repeats of control action in smaller interval.

Before finalizing a Queue we design an intermediate Que. Here priorities will be fixed. We will run 3 PID controllers with above Proportionality and Integral constants. But they will have 3 different derivative time constants depending on the prioritization at intermediate Ques.

The algorithms are both for Plant System -BS and BS-WSN BW allocations.

The procedure is as follow:

1. Polling for BW requirements is done.
2. All requests are sent to intermediate queue (buffer). Here requests are separated to ascertain the priority of the ques.
3. Assign suitable values of derivative constants to individual PID controllers so that Queue prioritization is maintained. Then requests are sent to respective PID controllers.
4. At individual PID controllers MV is calculated as per PID algorithm. Calculate the BW supply mismatch at previous two intervals. For smoother operation we may take more than two previous intervals. If there is continuous unfairness decreases the value of 'Ti'.
5. Total available BW is divided into 60%, 25%, and 15% for 3 Priority ques. These will be MVmax1,MVmax2 ,and MV max3 i.e. maxim mum values of manipulated variables for individual PIDs.

Example:Normally control loops work with 4-20 mA dc current signal for 0-100% control range .If f manipulated variable i.e. PID o/p from one controller is say 11 mA dc. Then corresponding BW is
(11-4)* 100/ (20-4) Eq.4

That is MV – mA corresponding to zero percent of BW Range (i.e. 4 mA dc) X100 percent of BW/ current span (i.e. 20-4). This MV is compared with MV max for that particular control loop. If it is less than BW is assigned. Else maximum possible BW (i.e. MV max for that queue) assigned.

Concept of Dynamic MV max.

We can transfer the residual BW from individual ques to other BW starved ques by suitable changes into algorithm. Suppose 30 percent is free with Priority I . 15% of this will be given to Priority II as it has Max MV 25 Its 15% consumed and 10% given (10+15=25 original MV Max). Rest 15% to Priority III.
Suppose Priority III has 10 % consumed. It will be given 10 % as 10+5 = 15% original MV max. Still 5 % will be left for priority I. But in reverse case BW will not be passed in this manner. Whenever there is no traffic in Priority II and III they will directly pass the Bandwidth to Priority I. Hence requests are sampled for a particular initial time and their arrivals are cumulatively taken. Suppose arrivals of traffic types 1, 2 and 3 are x1, x2, x3 then the available bandwidth at DCS is proportionally distributed as follows:

For traffic class 1, the band width to be assigned is
(x1 / x1 + x2 + x3) x 100
For traffic class 2, the band width to be assigned is
(x2 / x1 + x2 + x3) x 100
For traffic class 3, the band width to be assigned is
(x3 / x1 + x2 + x3) x 100

Here calculated Manipulated variable maxima above may not be commensurate with the total demand of traffic subsequently or may not meet QOS requirements of that particular class. This is compensated by Increasing the derivative time Td of the PID controller for that particular traffic type. There will be steeper slope and demanded BW will be assigned fast. So this particular traffic class will exhaust its allotted BW fast and ready for BW transfer from other traffic classes. If initially more BW is allotted there is always the provision of transferring BW from less demanding traffic class to BW hungry traffic class. suppose after sampling the arrivals we get arrivals of 50,60, 40 for traffic types, hence total arrival is 50+60+40=150,
MVmax for class I: (50/150) x 100 = 33.33%
MVmax for class II: (60/150) x 100 = 40%
MVmax for class III: (40/150) x 100 = 26.66%

The allotted MVmax for class I i.e. 33.33% may be less. Hence, we assign more Td for the PID controller for this traffic type. It will allot BW quickly; exhaust the allotted BW without transferring any BW in fact waiting for the unused BW at other traffic types. Here class II has been allotted 56%. It may be that it will not consume it because of either low Td of its PID controller or due to low demand.

Further we may take further samples of arrivals at fixed intervals of time and re calculate MVmax for that particular traffic type. After taking such regular samples at regular intervals' we may apply fore casting models for ascertaining future arrivals. There are many fore casting techniques such as moving average, Exponential smoothening and regression analysis. Suppose we have sample arrivals U1, U2, U3 for traffic type I at intervals t1, t2, t3 we can calculate traffic arrivals for the next instant t4.
i.e. U4 = U1+U2+U3/ 3.

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IV. SIMULATION RESULT

Here a simulation result with K_p =50,K_i=8,K_d=1as applied to a process of bandwidth allocation is depicted in Fig2. As in any process control system there will be initial oscillations which tend to slow down. With proper tuning of parameters Kp,Ki,Kd these can be made minimal. As can be seen bandwidth allocation becoming a smooth process which will lead to normal flow of traffic in a network.

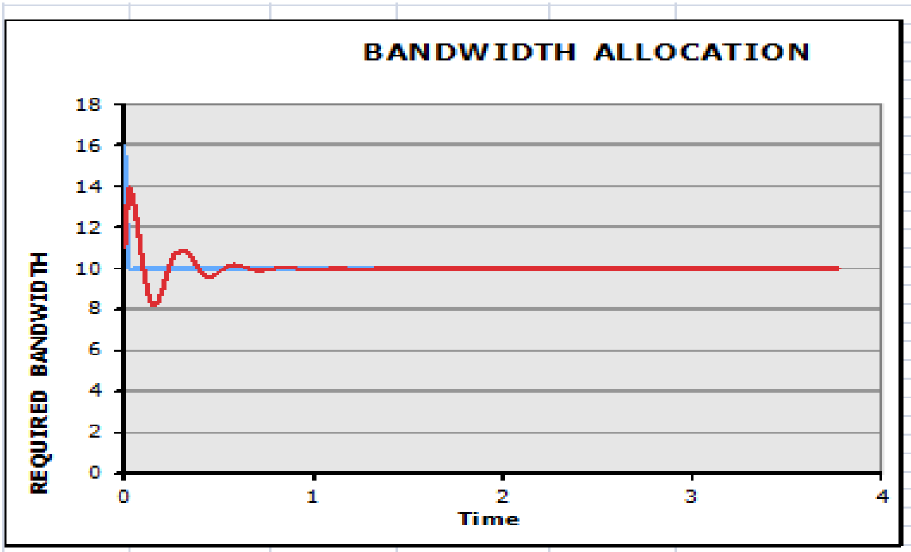

FIGURE 2: Bandwidth allocation wrt to Time.

V. CONCLUSION AND FUTURE WORK

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Here we have shown route discovery is possible in WSNs by fully utilizing time slots available between samples and variable sample rates for different parameters depending on their criticality. Further bandwidth allocation may be reasoned as a case of control of process. In future various control philosophies will be further applied to root discovery and bandwidth allocation.

REFERENCES

1. Vaidya Saurabh ,Ambad prashant,Bhosle Santosh Industry 4.0 – A Glimpse. Procedia Manufacturing, Volume 20, 2018, Pages 233-238
2. Gulati Kamal,Boddu Raja Sarathkumar,kapila Dhiraj,Bangare Sunil L,Chandnani Neeraj,Saravanan G(2022), "A review paper on wireless sensor network techniques in Internet of Things(IOT)", Materials today Proceedings,Volume 51, Part 1, 2022, Pages 161-165.
3. Adday Ghaihab Hassan,Subramaniam Shamala K,Zukarnain Zuriati Ahmad,Samian Normalia "Fault Tolerance Structures in Wireless Sensor Networks (WSNs)". Survey, Classification, and Future Directions.
4. Sensors 2022, 22(16), Pages 6041-6048.
5. Dunn Thomas (2015) 10-Basics Of Control Systems. Flexible Packaging materials, Machinery,and Techniques ,Pages 103-110.
6. Mehta B R, Reddy Y J(2015) Chapter 3 –Distributed Control System. Industrial Process Automation SystemsDesign and Implementation2015, Pages 75-133.

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