An Experimental Investigation of Premature Death of Sensor Node used in Io Tat Colder Environmental Conditions with Strategies to Mitigate the Same

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ABSTRACT

The Sensor Node Is A Vital Component Of Iot Technologies. The Main Objective Of This Paper Is To Study Theimpactofthesensorfieldenvironmentonthelifetimeofthebatteryofthesensornode.Specifically, Temperature, One Of The Environmental Parameters, Is Chosen For The Experimental Studies Undertaken In This Work. The Lifetime And The Power Consumed By The Sensor Node Are Analyzed At Different Temperatures. The Reasons For The Early Death Of The Battery Of The Sensor Node At Lower Temperatures Are Identified. Some Strategies Are Proposed To Overcome The Same. Experimental Results Have Shown The Life Of The Sensor Node Is 18% More When The Proposed Techniques Are Used.

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Introduction

Wireless Sensor Networks (Wsns) Have Attracted The Research Community Because Of The Challenges It Has Posed Due To Its Limited Resources. One Of The Vital Resources Of A Wireless Sensor Node Is The Energy Source. A Wireless Sensor Node Is Powered By A Primary Battery. Owing To The Smaller Size Of The Sensor Node, The Size Of The Battery Will Be Smaller, And Hence Available Energy With Which The Sensor Node Operates Will Be Limited. Thus The Life Time Of The Sensor Node Directly Depends On The Life Of The Battery.

Further, When The Wsns Are Deployed In Hostile Environments It Is Not Possible To Replace The Exhausted Batteries. Therefore There Is A Need To Use The Energy Of The Battery Minimally To Increase Its Life.

Specifically, When The Wsns Are Deployed In Colder Environmental Conditions, Experimental Investigations Have Shown That The Sensor Node Lifetime Has Been Shortened. Their Reduced Life Is Mainly Attributed To The Untimely Death Of The Battery That Drives The Sensor Node. The Strategies Adopted In This Paper Have Resulted In A Sensornodelifetimeenhancementof18%.

The Lower Mobility Of Ions In The Electrolyte At A Lower Temperature, Rate Capacity Effect, And Recovery Effect Of The Battery Are Found To Be The Major Causes For The Early Drain Of The Battery. The Reduced Mobility Of The Ions Will Appear As Increased Internal Resistance Of The Battery. Therefore, When The Load Is Connected To The Battery, Apart Of The Power Delivered By The Battery Will Be Dissipated By The Increased Internal Resistance Of The Battery. This Results In A Quick Drain Of The Battery.

The Sensor Node In The Transmitting Mode Increases The Discharging Of The Battery. This Increased Discharge Results In The Covering Of The Cathode Electrode With Inactive Reaction Zones And Thus Making Active Reaction Zones Unavailable. This Is Another Reason For Shortened Battery Life.

The Continuous Discharge Of The Battery Leads To Its Early Death As Compared To The Battery Usage In The Pulsed Mode. The Reason For This Untimely Demise Of The Battery Is Due To The Decrease In The Concentration Of The Positive Ions Near The Cathode And The Increase Of The Same Near The Anode. The Reason For This Untimely Demise Of The Battery Is Due To The Decrease In The Concentration Of The Positive Ions Near The Cathode And The Increase Of The Same Near The Anode. This Results In The Decreased Capacity Of The Battery.

This Paper Discusses The Strategies Which Have Been Adopted To Mitigate The Above-Discussed Problems.

1. Presentmethodologiesfor Enhancingthe Wsnslifetime

One Can Achieve Extension In The Lifetime Of The Wsns If The Transmission Of The Sensed Data Is Not Time-Critical. Store The Data And Transmit The Same When The Sink Node Is In A Favorable Position. In Impenetrable And Unfriendly Terrains, Lifetime Extension Becomes Very Important. In Such Conditions, One Of The Ways To Extract Intelligence Is To Deploy The Sensors Very Close. A Few Energy-Saving Approaches Were Proposed To Improve The Wsns' Lifetime [1].

An Inquiry-Based Approach Wireless Sensor System Has Been Investigated In Which A User Would Issue A Request And Anticipate A Response Within A Time-Bound Frame. Increasing The Lifetime Of Dissimilar Wsns Has Taken Place At A Sluggish Pace. Motivated By Ants, And Experimental Information, An Approach Hasbeen Formulated [2].Based On This Information, An Optimal Path On The Construction Graph Is Constructed To Increase The Number Of Coupled Covers. This Approach Is Used To Reflect The Interest Of Device Tasks. This Technique Has Resulted In The Extension Of The Lifetime Of Heterogeneous Wsns.

The Lifetime Improvement Of Wsns Of The Significant Level With Multiple Sinks That Have The Ability Of Locomotion [3] Has Been Reported.

In Time-Critical Applications, The Delay Is A Vital Factor. Hence, There Is A Need To Find The Shortest Path. A Mathematical Model Has Been Formed [4] By Deploying More Number Of Sensor Nodes.

Random Allocation Of Data To The Sensor Nodes Could Be A Reason For The Early Death Of The Sensor Networks. Alleviating This Problem Has Improved The Lifespan Of The Wireless Sensor Networks [5]. In This Approach, The Authors Presented Distinct Nodes Known As The Mobile Agent. Authors Have Considered A Technique Based On Energy Forecast Which Enabled These Special Nodes To Identify Approximately The Residual Energy In Their Cluster Comprising Of Other Sensors. This Approach Has Resulted In Circumventing The Problem Of Uneven Consumption Of Energy.

In Some Wireless Sensor Applications, There Could Be A Scenario Where Various Regions Involve Dissimilar Levels Of Sensing [6]. To Address This Bottleneck, The Authors Have Proposed A Multi-Objective Sleep-Scheduling Scheme For Differential Coverage In Wireless Sensor Networks To Attain A Better Trade-Off Between Coverage, Lifespan, And Energy Consumption.

The Use Of A Mobile Sink Reduces Energy Consumption. In This Direction, Work Was Reported [7].

The Depletion Of Nodes' Energy Results In The Death Of The Wireless Sensor Network. The Sensor Network Will Function Even When One Sensor Node Or Few Nodes Are Exhausted, Till The Sensor Nodes Data Reaches The Sink Node. Thus, The Wireless Sensor Network Lifetime Considers The Life Span Of All Sensors That Generates Valuable Data Of The Physical

Phenomenon. Work In This Direction Has Been Carried Out [8] With Reasonable Gains In The Lifetime Of The Sensor Network.

A Methodology Named The Coordination Of The Intra-Node [9] In The Case Of End-To-End Delivery Delay Constraints Has Been Investigated. It Resulted In Significant Gains In Wsn's Lifetime.

One Of The Approaches To Enhance The Wireless Sensor Network Longevity Is To Build A Work-Sharing Forwarding Tree Structure Placed At The Data Collecting Sink Node. But, This Could Result In A Long Path While Communicating With The Sink Node. It Is Unfavorable For Some Time-Critical Applications As Such Applications Require That All The Data Of Sensed Physical Phenomenon Required By The Sink Node. This Situation May Not Suit Some Mission-Critical Applications That Require All Sensed Data To Be Received By The Base Station With The Smallest Lag. An Investigation Is Carried Out In This Direction [10] With Positive Results.

By Adding Redundant Nodes, It Is Likely To Enhance The Operational Time Of The Sensor Network [11]. These Nodes Are Made Active At The Times When Any Active Node Is Exhausted Of Its Energy. Authors Have Used The Above-Discussedmethodbyproposingthelow-Energyadaptiveclusteringhierarchysparemanagementprotocol.

The Communication Unit Consumes The Chief Part Of The Battery Energy. There Is A Need To Mitigate The Problem Of The Early Death Of The Nodes Close To The Sink Node. The Network Lifetime Depends On The Reliability Of Thecommunicationpathandtheenergyofthenodesclosetothesinknode.Thesetwoproblemswereaddressed

[12]With Reasonable Life Time Gains.

A Technique Is Designed By The Authors [13] For Achieving The Optimum Life Of The Battery Of The Sensor Node Forsamplingintervallessthantheoptimumvaluebypopulatingthesensorfieldwithmorenodes.

Therandomnessthatexistsintheclusteringalgorithms resultsinclusterheadsmorethantherequired.Investigation In This Direction Has Been Undertaken [14] With An Approach To Control The Randomness Present In Leach's Clustering Algorithm.

Experimental Results [15] Have Shown That The Unwanted Cluster Heads Lead To Early Exhaustion Of The Sensor Network. To Mitigate This Problem, The Authors Have Adopted The Dynamic Cluster Head Selection Method For A Wireless Sensor Network.

The Minimum Energy Is Consumed By The Wsn If There Is Better Reliability Of Communication. Based On This, An Investigation Is Undertaken On The Grid-Based Routing Technique [16].

Unintelligent Discharge Of The Battery Results In Its Early Death. This Untimely Demise Of The Battery Of The Sensor Node Is The Result Of The Rate Capacity Effect Of The Battery. This Effect Has Been Mitigated By The Authors [17] Using An Ingenious Technique.

Information Reliability And Network Lifetime Are Two Important Attributes Of Wsns. The Work By Authors [18] In This Domain Has Resulted In Significant Improvement In The Wsns Lifetime.

The Uneven Distribution Of Data Among The Nodes Of The Wsn Is One Of The Reasons For The Shortening Of The Network Lifetime. The Problem Is More Severe In Unplanned Networks. A Strategy That Overcomes The Above-Discussed Problem Has Been Proposed [19] With Significant Improvements Over Existing Schemes.

Further, A Novel Battery Centric Approach Was Discussed [20, 21, 22, 23, 24, 25, 27, 28, 29] With Substantial Gains In The Lifetime Of The Sensor Node.

2. Meritsof Theproposedmethods

One Of The Main Reasons For The Quick Drain Of The Battery Of The Sensor Node Is Its Unintelligent Discharge. Rate Capacity And Recovery Effect Of The Battery Play A Vital Role Which Decides The Battery Lifetime. Further, The Sensor Node Parameters Viz. Sampling Interval And Power Level Of Transmission Have A Direct

Impact On The Recovery And Rate Capacity Effect Of The Battery Of The Sensor Node. An Arbitrary Choice Of The Sensor Node Parameters May Result In A Severe Rate And Recovery Effect Of The Battery Causing Its Quick Drain.

Further, When The Sensor Field Temperature Is Lower, The Rate Capacity And Recovery Effect Will Become More Severe. The Conditions Deteriorate When The Load Connected To The Battery Increases Leading To The Quick Discharge Of The Battery.

The First Strategy Used To Circumvent The Low-Temperature Problem Is To Compress The Data Before We Transmit Ittothesinknode.Huffmancodingisusedtocompressthedatainthepresentwork.

The Second And Third Strategies Are Based On A Kind Of Synchronization Between The Rate Capacity Effect And Recovery Effect With Sensor Node Parameters Viz. Power Level Of Transmission And Sampling Interval. When The Discharge Level Of The Battery Is High This Corresponds To A Higher Level Of Power Level Transmission, This Causes The Early Death Of The Battery Of The Sensor Node. Therefore, There Is A Necessity To Identify A Power Level Of Transmission So That The Rate Capacity Effect Is Minimal, And At The Same Time Not Compromising On The Data Received By The Sink Node.

The Lower Sampling Interval Put More Stress On The Battery Of The Sensor Node. An Arbitrary Choice For The Sampling Interval Which Happens To Be At The Lower End Would Be Detrimental And Result In The Quick Drain Of The Battery. The Reason For Its Early Exhaustion Is Due To Insufficient Idle Time At The Lower Sampling Interval Of The Sensor Node. Hence, There Is A Need To Identify The Value Of The Sampling Interval, So That The Battery Of The Sensor Node Gets Enough Time To Idle During Which It Regains Its Previous Voltage. This Results In An Improvement In The Battery Life Of The Sensor Node.

3. Experimentalarrangement

Sensornodesarefabricatedandeachsensornodeconsistsofthreesensorsviz.Temperaturesensor,Accelerometer, And Light Sensor. These Sensors Are Interfaced To The Microcontroller Via Lm324. It Is A Quad Op-Amp Integrated Circuit From Texas Instruments. The Microcontroller Used In The Present Work Is Pic18f252made By Microchip. A Lithium-Ion Battery With The Specification Of 2200mah, 3.7v Is Chosen. Three Such Batteries Are Used To Energize Each Sensor Node. Ic7805is Used To Provide Regulated Five Volts To The Microcontroller Through Ic 2941 For Supply Efficiency Improvement. Wireless Communication Between The Nodes Is Facilitated By Cc2500 Transceiver. The Same Transceiver Is Embedded Into The Sink Node. The Receiver Node Output Is Interfaced To The Computer To Save The Experiment Results. The Experimental Arrangement Is Asshowninthefigure.1

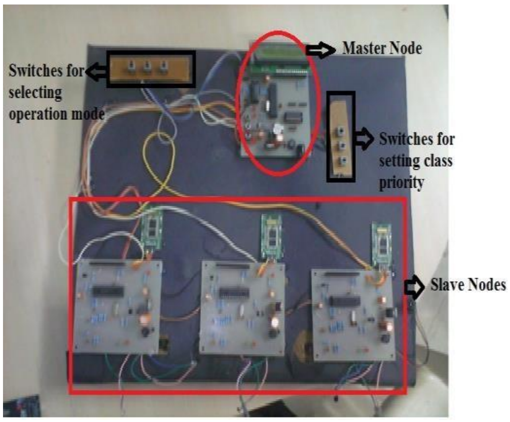

Figure1.Experimentalarrangementofthefabricatedsensornodes

4. Experimentalresults

4.1. Lifetimeofthesensornodeatvarioustemperatureswithoutdatacompressionandwithdatacompression

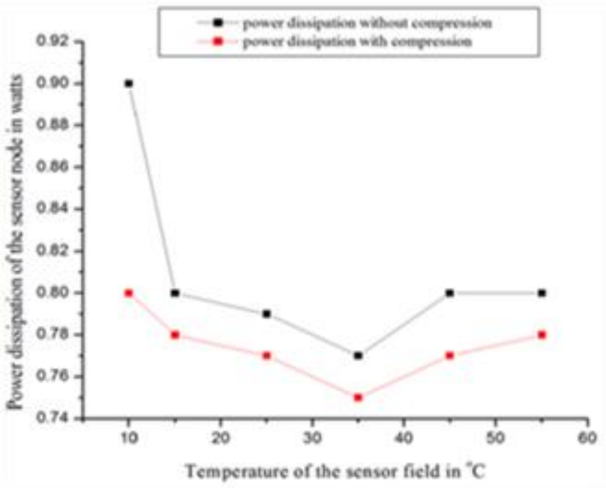

Figure2.Thegraphshowsthepowerdissipationofthesensornodeversustemperatureofthesensorfieldatasamplingintervalof0.2seconds

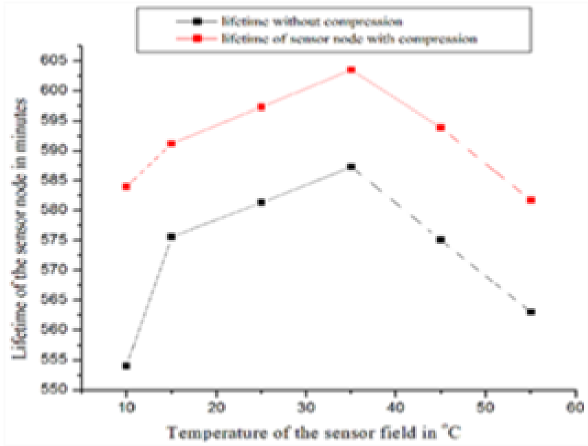

Figure 3.The Graph Shows The Life Time Of The Sensor Node Versus The Temperature Of The Sensorfieldatasamplingintervalof0.2 Seconds

As Illustrated In Figure 2, The Power Dissipation Is 0.9 Watts At 10oc. However, When The Data Compression Is Applied, The Power Consumed By The Sensor Node Has Decreased To 0.8 Watts. Thus The Data Compression Has Resulted In A Power Dissipation Improvement Of 11.11%.

At15°c, The Improvement In The Dissipation With Data Compression Is 2.5%.

The Investigative Studies Have Revealed That The Decrease In The Lifetime Of The Sensor Node At Colder Conditions Is Due To The Reduced Mobility Of The Ions Flowing Through The Electrolyte Of The Battery. The Reduced Mobility Of The Ions Manifests As Increased Internal Resistance Of The Battery. Thus, When The Battery Is Discharged, A Reasonable Component Of The Energy Of The Battery Is Dissipated By Theinternalresistanceofthebatteryleadingtoprematureexhaustionofthebattery.

It Is Evident From Figure 2 That With The Increase In Temperature There Is A Decrease In The Power Dissipation Of The Sensor Node. This Trend Is Observed Up To 35°c. However, There Is A Marginal Increase In The Power Dissipation After 35°c. This Rise In Power Dissipation Could Be Attributed To Battery Self-Discharge Of The Sensor Node At A Relatively Higher Temperature.

These Results Agree With The Anticipations Made In The Earlier Part Of This Paper.

Figure 3 Illustrates The Effect Of The Sensor Field Temperature On The Lifetime Of The Sensor Node. At 10oc, The Sensor Node Lifetime Is 554 Minutes Without Data Compression. However, The Lifetime Has Increased To 585minutes With Data Compression. This Improvement In The Lifetime Is Equivalentto5.29%.

At 15°c, The Sensor Node Lifetime Is 575 Minutes Without Data Compression. It Increases To 592 Minutes With Datacompression.Itisequivalentto2.8%Enhancementinthesensornodelifetime.

Thistrendcontinuesupto35°c.However, After This Temperature, The Lifetime Decreases Even With The Increase In Temperature.Thiscouldbeduetotheself-Dischargeofthesensornodebatteryatrelativelyhighertemperatures.

5.2 Lifetime Of The Sensornodeat Various Temperatures With Optimum Sampling Interval.

An Algorithm Has Been Designed By The

Authors To Find The Optimum Sampling Interval Of The Sensor Node. From The Experimental Results, It Is Evident That Operating The Sensor Node At An Optimum Value Has Resulted In Reduced Power Consumption.

In The Present Work, The Optimum Value For The Sampling Interval Is Found To Be 0.62 Seconds. At 0.62 Seconds, The Power Dissipated By The Sensor Node Is 0.35 Watts. However, When The Sensor Node Sampling Interval Is 0.2seconds, The Power Dissipation Of The Node Is 0.78watts. Thus Operating The Sensor Node At 0.62 Seconds As Compared To Its Operation At 0.2 Seconds Consumes 55% Less Power. Further, The Lifetime Of The Battery, Which Is The Lifetime Of The Sensor Node Operated At 0.62 Seconds Is 722 Minutes, Whereas The Lifetime At 0.2 Seconds Is590 Minutes. This Is Equivalent To 18% Improvement In The Sensor Node Lifetime When Operated At The Optimum Value. Therefore, It Is Evident That An Arbitrary Selection Of The Sampling Interval Would Result In A Lower Lifetime For The Sensor Node.

Now The Sensor Node At The Lower Temperature Is Operated At The Optimum Sampling Interval To Enhance Its Lifetime.

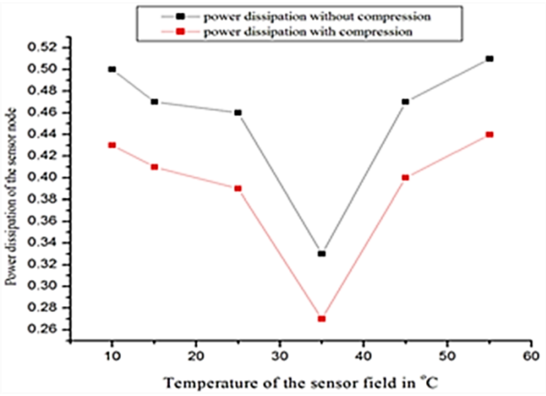

Figure4.Thegraphshowspowerdissipation Versustemperatureatthesamplingintervalof0.62seconds

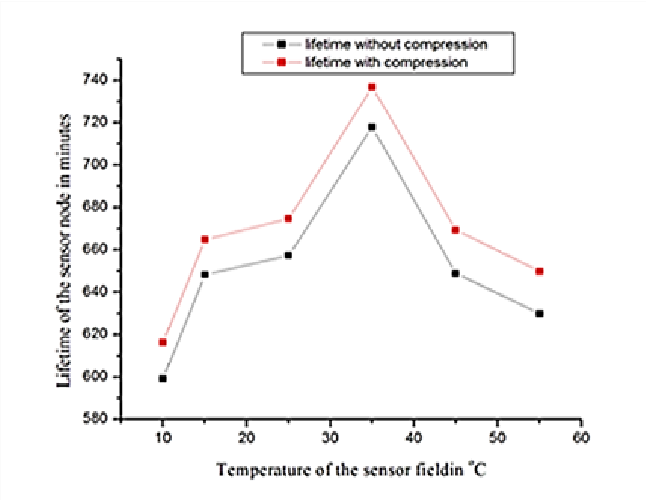

Figure5.Thegraph Shows Lifetime Versus Temperatureatthesamplingintervalof0.62seconds

Figure 4 And Figure5 Show The Graphs Of Power Dissipation And The Sensor Node Lifetime To The Temperature At The Optimum Sampling Interval Of 0.62 Seconds. The Improvement In The Lifetime At 35oc Is 24.81% With Data Compression And 22.82% Without Data Compression As Compared With Their Values At The Sampling Interval Of0.2seconds.

5. Conclusion

For The Successful Operation Of Iot Technologies, Sensor Nodes Must Perform Well. The Longevity Of Sensor Nodes Is Also An Important Parameter From The Purview Of Economics. When The Iot Technologies Depend On The Information Generated By The Sensors, Which Are Placed In Detrimental Conditions Like Colder Environmental Conditions, Sensor Nodes Must Have Extended Lifetimes. The Studies Conducted During The Research Revealed Thatthelifetimeofthesensornodereducestoalargerextentowingtotheprematureexhaustionoftheelectrochemical Battery. Using The Strategies Of Data Compression And Operating The Sensor Node At An Optimumsamplingintervalof0.62seconds, The Sensor Node Lifetime Is Improved By18%.

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