A Study on Traffic Adaptive MAC Protocols for Wireless Body Area Network

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Abstract.

AwirelessBodyAreaNetwork(WBAN)isexpectedto beaveryusefultechnologywithpotentialtoofferawide rangeofbenefitstopatients,medicalpersonnelandsociety throughcontinuousmonitoringandearlydetectionofpossible problems.Anenergy-efficientMediumAccess Control(MAC) protocolisrequiredtosatisfythestringentWBAN requirements.Itisstillinprogressingstageand implementationofthestandardisnotyetfinalized.Inthis study,IdiscussedvariousMACprotocolsproposedby researchpeersspecificallyaddressedtheneedsofWBANand finallyconsideredthatbyadoptingthecognitiveapproach throughtrafficconsiderationtheMACProtocolinWBANcan reducetheenergywastagesinWBANsensors.Ihave consideredheresinglehopmasterslavestartopologyforthe network.TheIEEE802.15.4standardprovidesthe widely acceptedsolutionforlow-costandlow-powerwireless communications.Despiteitsdesign,thefixedsuperframesize inBeacon-enabledmodelimitsitscapabilitiesduetotwo contrastinggoals;energyefficiencyandhigherdata throughput.Inthispaper,Ioutlinedthatanenhancementof IEEE802.15.4 Beacon-enabledmode whichadaptivelyadjusts theactiveperiodbasedonthetraffic- loadresultinginenergy savingofdevices.

Keywords: MAC;WBAN;BSN;low-power

I. INTRODUCTION

AWirelessBodyAreaNetwork(WBAN)[1]consistsofsmall,intelligentdevicesattachedonorimplantedinthebodywhicharecapableofestablishingawirelesscommunicationlink.Thesedevicesprovidecontinuoushealthmonitoringandreal-timefeedbacktotheuserormedicalpersonnel.Oneofthecrucialareasinimplantingsensorsisthebatterylifetime.Batteriescannotbereplacedorrechargedwithoutemployingaseriousmedicalproceduresoitisexpectedthatbatterypoweredmedicaldevicesplacedinsidethebodyshouldlastfortentofifteenyearsaccordingtospecificapplication.Networkingplacesanextrademandonthetransceiver andprocessing

operationsofthesensor resultinginincreasedpowerconsumption.Anetworkplaced underahardenergyconstraint mustthereforeensurethatallsensorsarepowereddownorinsleepmodewhennotinactiveuse,yetstillprovidecommunicationswithout significantlatencywhenrequired.Usingwirelesscommunication,insteadoftraditionalwired connections,inhealthcaresystemsnotonlyreducesthemaintenancecost,andgivesthepatientsmorefreedomand comfort,butalsomakespervasiveandmobilehealthcarepossible.Itcanhelpphysicianstoperformearlydiagnosisandtreatment, anddevelopandverifynewtherapiesthroughcontinuously monitoringandanalyzinghumanvitalsigns.AsshowninFig.1,aBSNusuallyconsistsofimplantableorwearablebiosensors,andmeasurethetemperature,bloodpressure,heart rate,ECG,EEG, respirationrate, SpO2-levelsetc.Itincludeseveningestible camerapills.Thesesensorscontinuouslymonitorvitalsigns andreportdatatoa powerfulexternaldevice,such asapersonaldigitalassistant(PDA),acellphone,or awrist-wornsmartwatch.

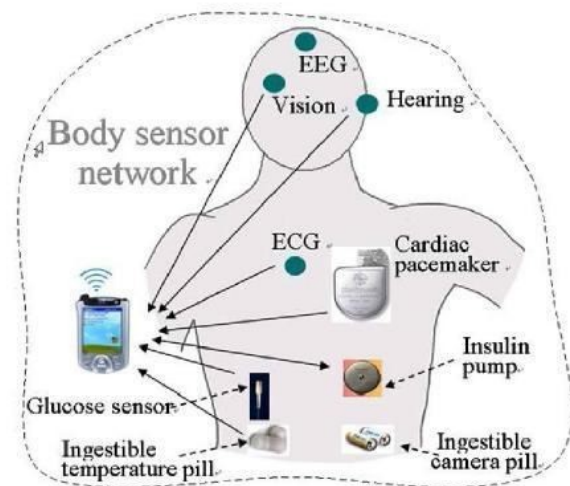Fig.1.BSN consistingofvariouswirelessbiosensors.

Oureraiswitnessinganincreasingpressureonqualityandquantityofhealthcareduetotheincreaseofagingpopulation,chronicdiseases,andhealthconsciousnessofpeople.BANsoonwillbeingreatdemand.

ThenumberofMAC-protocolsspecificallydevelopedforWBANsislimited.TwomajorcategoriesofMAC-protocolsarecontention-basedandschedule-based.Fortheformer,CSMA/CAisatypicalexample,whileTDMAisatypicalschemeforthelatter.Theadvantagesofcontention-basedapproachesarethesimplicity,itsinfrastructure-freeadhocfeatureandgoodadaptabilitytotrafficfluctuation,especiallyforlowload.Schedule-basedapproachesontheotherhandarefree ofidlelistening,overhearingandpacketcollisionsbecauseofthelackofmediumcompetition,butrequiretighttimesynchronization.

InspecifyingthisMACProtocol,thefollowingattributescanbeinferredaboutthewirelessbodyareasensornetwork.

1. Allwirelesssensor nodesareattachedtothe body.
2. Thedatabeingmonitored isoflowfrequency.
3. Sensorsmonitorarangeofvitalsignswhicharetypicallyatalowdatarate(<1kB).
4. Sensornodesareresourceconstrained,i.e.,theyhavelowprocessingpowerandlimitedmemory.
5. Datafromthewirelesssensornodesisforwardedtoacentral masternode forprocessing;thiscentral node issignificantlylessresourceandpowerconstrainedrelativetothewirelesssensornodes.

II. RELATEDWORK

ThistermwasfirstcoinedbyVanDamin2001[1]andreceivedtheinterestofseveralresearchers.SomeimplementationsofWBANsuseBluetooth(IEEE802.15.1).Thiswasdevelopedasacablereplacementanddoesnotsupportmulti-hopcommunication.IthasacomplexprotocolstackandahighenergyconsumptioncomparedtoIEEE802.15.4.Itisthereforenotsuitedtobeusedina WBAN.MostcurrentimplementationsofWBANs useIEEE802.15.4orZigBee asenablingtechnology.AsmostoftheradiosusedinaWBANarebasedonanIEEE802.15.4compliantchipset,someresearchershaveadaptedtheIEEE802.15.4MAC-protocoltomakeitmoresuitableforWBANs.

Forthefirsttime,**NicholasF.TimmonsandWilliamG.Scanlon**[2]presentedan analysisoftheperformanceoftheIEEE802.15.4lowpower,lowdataratewirelessstandardinrelationto medicalsensorbodyareanetworks.Themainconsiderationinthisworkwasthelong-termpowerconsumptionof devices,sinceforpracticalreasons,implantedmedicaldevicesandsensorsmustfunctionforatleast10to15yearswithoutbatteryreplacement.Theresults showthatwhenproperlyconfigured,802.15.4can beusedfor medicalsensor networkingwhenconfiguredinnon-beaconmodewithlowdatarateasymmetrictraffic.

- Thispaperfocusedonananalysisofthe802.15.4standardconfiguredasastarnetworkwherethecoordinatingdeviceisexternaltothebody,e.g.,incorporatedinaPDA,mobiletelephoneorinbedsidemonitoringstation.
- Descriptionofthenetworkwas starnetwork consistedofthecoordinatorand10bodyimplantedsensors.

In IEEE802.15.4,each nodecan employa CSMA/CAprotocol to avoid power-consuming collisions whenmultiple simultaneous transmissions may occur. TheCSMA/CAprotocol usedin 802.15.4canbeslottedorunslotted.IfabeaconisbeingusedtheslottedCSMA/CAisemployedintheCAPpartofthesuperframe.Ifanon-beaconnetworkisused,orifthebeaconisnotdetected,then unslottedCSMA/CA is employed. In slottedCSMA/CAthestartofthefirstback-offperiodofeachnodeisalignedwiththestartofthebeacon.InunslottedCSMA/CAthereisnolinkintimebetweenthebackoffperiodsofanynode. Therearethreevariablesmaintainedbyeachnodeforeachtransmissionattempt:NB,CWandBE.

Inthefirststudyofitskind,thelowpowerperformanceofthreemodesoftheIEEE802.15.4standardwereevaluatedinrelationtoabodyareanetworkofimplantedmedicalsensors.Themodesevaluatedwerebeacon,beaconplusguaranteedtimeslotsandnon-beacon,allat2.4GHz.Ina**non-beacon**enablednetworkdataframesaretransmittedusingunslottedCSMA/CA.

- Whencommunicationisfromthenodeto thecoordinator,thecoordinatoracknowledgessuccesfulreceptionofthedataframeby sendingbackan acknowledgementframe.
- Whenthecoordinatorwishestosenda dataframetoanode,itmustwaituntilitreceivesadatarequestfromthesensor.

Ina**BeaconenablednetworkwithGTS**

- Whencommunicationisfromthenodeto thecoordinator,ifGTSwasassigned,itwillsendthedata framewithinappropriatetime slot.IfnoGTSisassignedthesensortransmitsitsdatainCAPusingCSMA/CA.
- Whenthecoordinatorwishestosenda dataframetoanode,itsendsaflagin thebeaconframeindicatingthata message is pendingforaparticularsensor.Onreceiptofthistheappropriatesensorwilltransmit,usingCSMA/CA,adatarequestMAC commandframe,indicatingtothecoordinatorthatitmaytransmitthedata.Thecoordinatorwillsendanacknowledgmentframefollowedbythedataframe.IfithasaGTSassigneditwillsendthedataframewithintheappropriatetimeslot.IfnoGTSisassignedthesensortransmitsits data

frameintheCAP,usingtheCSMA/CAprotocol,ifen abled.

Itwasshownthatbeaconoperationwasonlypossibleasasolution tothechallengeofthebodyareanetwork.TheIEEE802.15.4stan dardwouldprovidealimitedanswerinitsnon- beaconform.Sensorsthatdonothavelargeamountsofdatatotran sfercouldbeused,i.e.,smallpacketsofdataseveraltimes   per hour.

AnotheranUltra-low- powerMediumAccessControlProtocolforBodySensorNetwo rkproposedby**HuamingLiandJindongTan**[3].BSN- MACisanadaptive,feedback-basedandIEEE802.15.4- compatibleMACprotocol.BSN- MACexploitsthefeedbackinformationfromthedeployedsenso rstoformaclosed- loopcontroloftheMACparameters.ThispaperproposedBSN- MAC(BodysensornetworkMAC),whichisadedicatedultra- low-power   MAC   protocoldesignedforstar topologyBSNs.BSN- MAChasgoodcompatibilitywithIEEE802.15.4aswellasacco mmodatesuniquerequirementsofthebiosensorsinBSNs. BSN- MACisdesignedtobeanadaptiveMACprotocol.Byexploitingf eedbackinformationfromdistributedsensorsinthenetwork,BS N- MACadjustsprotocolparametersdynamicallytoachievebesten ergyconservationonenergycriticalsensors.Theyintroducedtw otradeoffs   in   BSN- MACdesign.Thefirstisbetweentheenergyofcoordinator(unco nstrained)andthelifeofenergy- criticalsensorsnodes.Thesecondisbetweenthesensordatarepo rtdelayandthelifetimeofenergy- criticalsensorsnodes.Oncethenodepowersupitsradioandgetss ynchronized, dependingonthebeaconinformationandbuffereddatasize,iteit hersendsoutadatatransmissionrequest(REQ)packetfollowed bypartofthesensorydataorsendsoutthesensorydatadirectly.Af terthenodesynchronizeswiththecoordinator,bydecodingtheb eaconframe,the   nodelearnsthe lengthofthebeaconintervalandunderstandswhetheritcantrans mititsdataduringasinglebeaconinterval.Ifyes,itwillstarttrans mittingitsdatadirectly.Otherwise,thenodesendsoutaREQpac ketfirsttoaskthecoordinatortochangethebeaconinterval.TheR EQpacketincludesthePMACofthesensor,whichisusedbythen etworkcoordinatortodeterminetheprioritywhenmultipleREQ sarereceived.

$$P_{MAC} = \frac{2^{EL+1} \times T_c}{E_R \times B_R}$$

Here   EListheenergyconstraintlevel.0 to3areassignedtoenergyunconstrained,constrained,highconst rained andextremelyconstrainedsensorsrespectively.TCisthecritical ityindexofthesensorydata.ERrepresentstheenergyremainingl

evelandischosenfrom1to3.BRrepresentstheremainingbufferlevelof asensorandisassignedfrom1to3.Thesensorcannotalwayschangethe MACparametersastheirwillsincewhentheMACparametersarechan gedto favoracertain
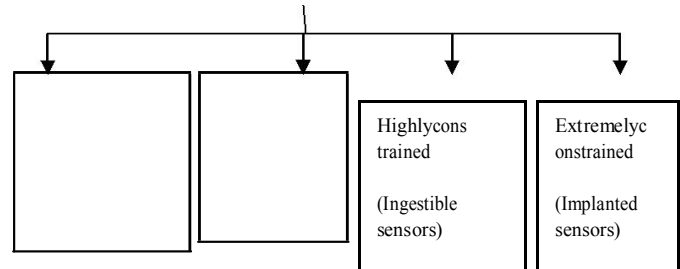
node,othernodes maysufferfromit.PMAC(mediumaccesspriority)isdetermined bytheenergyconstraintlevel,datatimecriticalityandtheremaining energyandbufferlevel.Wenoticethatall theinformationneededtocalculatePMACisavailableonthesensors'side.

Categoryof sensorinBSNbasedonenergycriticallevel

Unconstrained
Constrained

(PDA)   (WearableSensors)

*(TXSlot),ReceiveSlot(RXSlot),ReceivetoSynchronizeSlot(RXSSlot)*and*Stand BySlot(SBSlot)*.

Highlyconstrained

(Ingestible sensors)

Extremelyconstrained

(Implanted sensors)

Therefore,onlythenodeswiththehighestmediumaccess prioritycanrequestthecoordinatortochangethebeaconinterval freely.Alltheothersensorsmaychangethebeaconintervals,butnot thatsignificantly.RBN is usedbythesensorstodescribehowmanysuchrequestedbeacon intervalstheyneedtotransmitthecurrentdata.

Acrosslayer designstrategyis adoptedinBSN-MAC.Thenetworkcoordinatorandthesensors interacttoachieveefficientpowermanagement.Thecoordinator controlsthecommunicationbyvaryingthesuperframestructure.Thesensorsproviovidereal-timefeedbacktoBSNcoordinatorwithapplication-specificandsensor-specificinformation.Hence,theBSNcoordinatorcanmakedynamicadjustmentbasedonthefeedbacktoachievebetterperformanceinenergyefficiencyandlatency.

OneofthefewMAC-protocolsforWBANswasproposedby**Lamprinos**[4].Itincorporatesmaster-slavearchitecture,withallmedicalsensornodesbeingdesignatedasslaves,whiletheadministratingnodeactsasthemasterofthepatientPAN.Theapplicationsoftwareofthemasternodenormallyinitiatesdataexchange,bytransmittingsetupinformationtotheslavenodes.Eachsensorisassignedauniqueaddress,andthesystemhasagloballyuniqueaddress.

- Transmissionfromslavestomasterisbasedona Requesttosend–Allow tosendscheme.Theexchangeofdataissupportedbyoptionalacknowledgement,retransmissionsandmaybesubjectedtoerrorcorrection,usingForwardErrorControl(FEC)toensurenodataloss.Inordertoavoidcollisionsandchanneloverhearingandadministratetheexchangeofdatainthecommunicationchannel,thetimelinewasbreakinfourtypesoftimeslots,namely*Transmit Slot*

- In particular, if a node has data to transmit, it can execute the respective procedure only at the fade-in of a TX Slot.
- Accordingly, reception of data can occur only during RXS lot or RXS Slot.
- The RXS Slot is a type of RX Slot implemented only in the slave nodes. It differs in the sense that it endures longer and is used for the synchronization of the slave with the master.
- Finally, both master and slave nodes switch off their transceiver during StandBy Slot. During this period, no transmission or reception activity takes place.

    The main drawback of this protocol is that some slaves will have a low duty cycle whereas the nodes that are serviced later have a higher duty cycle.

Fig.2. Time slot alteration and data exchange between master and slave nodes

According to the author of this proposed scheme, the sequence and duration of time slots is predefined. Initially, the slave node alternates between SB Slot and RXS Slot. During RXS Slot, it listens to the communication channel and if it tracks down a packet designated for it, it calculates an offset time, combining the length of the received packet, the predefined duration of time slots and the transmission bit rate in order to accommodate its transition from RXS Slot to TX Slot to the master's transition from TX Slot to RXS Slot.

The general idea of the proposed synchronization procedure is that after the reception of the first packet, the slave adapts an alteration of time slots which results in being in TX Slot whenever the master is in RX Slot and inversely. All the nodes of the network are in SB Slots simultaneously. These features are depicted in Fig.2, where time slot alteration and data exchange between the master and two slave nodes are represented.

The main drawback of this protocol is that some slaves will have a low duty cycle whereas the nodes that are serviced later have a higher duty cycle.
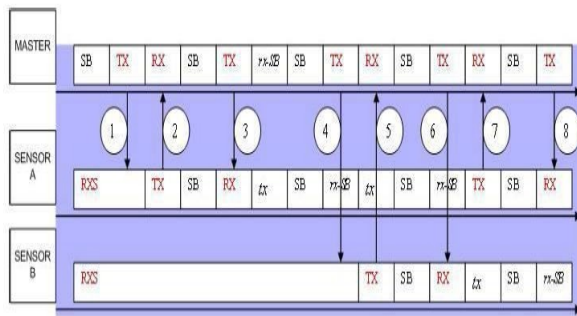
1.C.O meni,0.Eljamaly,A.J.Burdett[5] propose a MAC protocol for a star-networked WBAN that supports TDMA to reduce the probability of collision and idle listening. Each slave node is assigned a slot by the central node. When an alarm occurs at one of the nodes, the node can be assigned an extra slot for direct communication. The protocol has been evaluated on a Sensium platform. The proposed MAC protocol operations are based on three main communication processes.

- The first is when a wireless sensor node wants to join a cluster. This is called the Link establishment process.
- The second is when a slave and master wake-up after an assigned sleep period. This is called the wakeup service process.
- The last process is an exception process which occurs when a slave urgently wants to send information to the cluster master. This is called an Alarm process.

In all 3 processes, communication can only be initiated by the master. In addition only one slave can join the network at a time as the network is non-adhoc.

The **H-MAC** protocol[6] uses the human heartbeat rhythm information to perform time synchronization for TDMA. The biosensors can thus achieve time synchronization without having to turn on their radio. The algorithm is verified with real world data but assumes a certain buffer. As a TDMA protocol, H-MAC assigns dedicated time slots to each biosensor to guarantee collision-free transmission. On the other hand, by taking advantage of heartbeat rhythm that is inherent in every human body, H-MAC achieves TDMA time synchronization without distributing periodic timing information, which reduces the energy cost. In H-MAC, biosensors extract the necessary synchronization information from their own sensory biosignals, which are correlated with or directly driven by the heartbeat pulsation, in a distributed way.

H-MAC considers time slot scheduling for one hop star topology BSNs. Since the traffic pattern in BSN is data logging and the network coordinator is the common receiver of the transmissions, only one sensor node is allowed to transmit in a time slot to avoid collisions. In H-MAC, we use the peaks as synchronization beacons and use peak interval as time slots for data transmission. By introducing a peak counter in each biosensor, we can assign dedicated time slots to each biosensor for collision-free network transmission.

III. Standard of WBAN MAC Protocol

Most current implementations of WBAN suse IEEE 802.15.4 or ZigBee as enabling technology. As most of the radios used in a WBAN are based on an IEEE 802.15.4 compliant chipset. IEEE standard 802.15.4[7] intends to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices, intending to exploit this to lower power consumption even more.

The basic framework conceives a 10-meter communications range with a transfer rate of 250 kbit/s. Lower

transferratesof20and40kbit/swereinitiallydefined,withthe100kbit/sratebeingaddedinthecurrentrevision.Asalreadymentioned,themainidentifyingfeatureofIEEE802.15.4amongWPANs   isthe importanceofachievingextremelylowmanufacturingandoperationcostsandtechnologicalsimplicity,withoutsacrificingflexibilityorgenerality.Importantfeaturesincludereal-timesuitabilitybyreservationofguaranteedtimeslots,collision avoidancethroughCSMA/CAandintegratedsupportforsecure communications.Devicesalsoincludepowermanagementfunctionssuchaslinkqualityandenergydetection.IEEE802.15.4-conformantdevicesmayuseoneofthreepossible frequencybands foroperation.
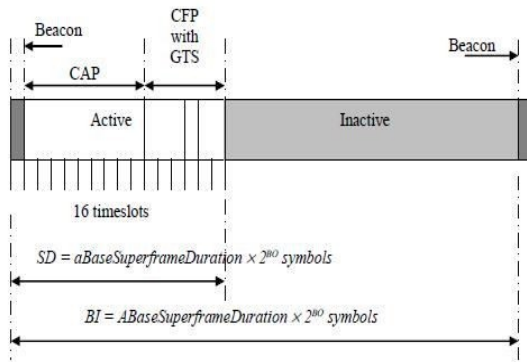

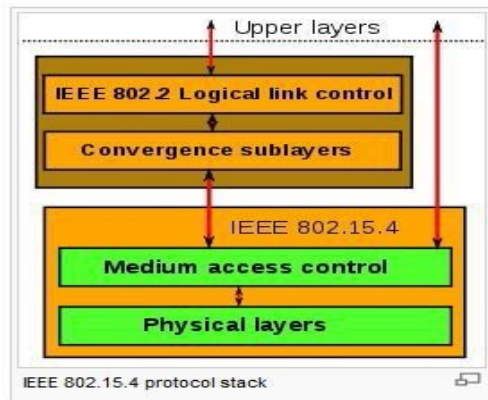Fig. 3.IEEE 802.15.4Superframestructure

IV. PROTOCOLARCHITECTURE

Fig.4.IEEE802.15.4protocolstack

A. Thephysicallayer

Therearetwophysicallayervariantsin802.15.4:868/915MHzand2.4GHz(TABLEI).Thestandarddefinesthe   868MHz bandasasinglechannelwitha   datarateof20   kbps,the915 MHzbandasasingle40kbpschannel,whilethe2.4GHzbandis dividedinto16channels   eachwitha   datarate of250kbps.Forconvenience,thisworkconsidersonly2.4GHz.

TABLEI

802.15.4PHYSICALPARAMETERS

Frequency Band	Bit Rate	Symbol Rate	DSSS Spreading Parameters	
			Modulation	Chip rate
868-868.6 MHz	20 kb/s	20 ks/s	BPSK	300 kc/s
902-928 MHz	40 kb/s	40 ks/s	BPSK	600 kc/s
2.4-2.4835 GHz	250 kb/s	62.5 ks/s	O-QPSK	2 Mc/s

B.TheMAClayer

The*mediumaccesscontrol*(MAC)[1]enablesthetransmission ofMACframesthroughtheuseofthephysicalchannel.Twotopologiesaresupportedby802.15.4:starandpeer-topeer,buthereonlystarnetworksisconsidered.Themainadvantageofusingastarnetworkformedicalsensorapplicationsisthat anexternalcoordinatorcanbeusedwithaccesstorechargeablepowersupply.Withthestartopologytherearetwocommunicationmethods:beaconmodeandnonbeaconmode.

In**beaconmode**,communicationiscontrolledbythenetwork coordinator,whichtransmitsregularbeaconsfordevicesynchronizationandnetworkassociation control.Thenetworkcoordinatordefinesthestartandendofasuperframebytransmittingaperiodicbeacon.Thelengthofthebeaconperiodandhencethe   duty   cycleofthesystemcanbe definedbytheuserbetweencertainlimits asspecifiedinthestandard.Theadvantageofthismodeisthatthecoordinatorcancommunicateatwillwiththenodes.Thedisadvantage isthatthenodesmustwakeuptoreceivethebeacon.

In**non-beaconmode**,anetworknodecansenddatatothecoordinatorat willusingCSMA/CAifrequired.However,toreceivedatafromthecoordinatorthenodemustpowerupandpollthecoordinator.Toachievetherequirednodelifetimethepollingfrequencymustbepre-determinedbypowerreservesandexpecteddataquantity.Theadvantageofnon-beaconmodeisthatthenode'sreceiverdoesnothavetoregularly power-uptoreceive   thebeacon.Thedisadvantage isthatthecoordinatorcannot

communicateatwillwiththenodebutmustwaittobeinvitedbyth enodetocommunicate.

Inbeaconmode,thesuperframemayconsistofbothanactiveandi nactiveperiod(Figure3).Theactiveportionofthesuperframe,w hichcontains16equallyspacedslots,iscomposedofthreeparts:a beacon,acontentionaccessperiod(CAP),anda contentionfree period(CFP).ThebeaconistransmittedwithouttheuseofCSMA atthestartofslot0andtheCAPcommencesimmediatelyafterthe beacon.Thecoordinatoronlyinteractswithnodesduringtheacti veperiodandmaysleepduringtheinactiveperiod.There isaguaranteedtimeslot(GTS)optionin802.15.4toallowlowerl atencyoperation.Thereareamaximumof7ofthe16available timeslotsthatcanbeallocatedtonodes,singlyorcombined.

Whenanodeisallocatedatimeslotitmayonlytransmitdatadurin gthattimeslot.GTSnodesmustlistentothebeacontosynchroniz epriortocommunicationwithinitsallocatedtimeslot(s).Therela tivesizeofeachoftheactiveandinactiveperiodsisdeterminedby the

valuesofthe*macBeaconOrder*(*BO*)andthe*macSuperframeOr der*(*SO*)andtheoverallsuperframelength(or*BeaconInterval,B I*)andactivesuperframeduration(*ASD*)arecalculatedasfollows :

$BI=(aBaseSlotDuration \times aNumSuperframeSlots \times 2^{BO})$symb-ols

where$0 \le BO \le 14$,aBaseSlotDuration=60symbols andaNumSuperframeSlots(slotsinaframe)=16

$ASD=(aBaseSlotDuration \times aNumSuperframeSlots \times 2^{SO})$sy-mbols
where$0 \le SO \le BO \le 14$

C. Higherlayers

Otherhigher-levellayersandinteroperabilitysublayersarenot definedinthe   standard.There existspecifications,suchas6LoWPANandZigBee,whichbuild onthisstandardtoproposeintegralsolutions.TinyOS,UnisonR TOS,DSPnano   RTOSandContikistacksalsouseafew itemsofIEEE802.15.4hardware.

V.   ADAPTINGOFDATA TRAFFICINIEEE 802.15.4

IEEE802.15.4WPAN(WirelessPersonalAreaNetworks)stan dard[8]supportsforlow-costandlow-powerwirelessconnectivityamongresource-limiteddevices.Especially,IEEE802.15.4MACachievesalow-dutycycleoperationbymeansofitsBeacon-enabledmode.Inthis mode,aPANcoordinatorperiodicallydisseminates*asuperfram e*structureboundedbyabeaconframeintothenetworkandmana gesitsactive/inactiveperiod.Anyassociateddevicesareallowed tocommunicateintheactiveperiodandconserveenergybyturni ngofftheir transceiversduringtheinactiveperiod.However,a fixeddurationoftheactive

periodlimitsitsoverallperformancebytwomeans:idlelistening andlower   data throughput.Inthispaper,Istudiedanovelschemeformitigatingt heidlelisteningproblemand improvingdata throughput in the current IEEE 802.15.4Beaconenabledmode.Inthisscheme,acoordinatorcan adaptivelyadjusttheactiveperiodbasedonthedata trafficinformationofassociateddevices.Whenadatatrafficloa dislow,theactiveperiodisreducedtoconserveenergyconsumpt ionregardlessofasuperframeduration.However,withahighert rafficloadtheactiveperiodbecomeslengthenuptoatotalbeaconi ntervaltoimprovedatathroughput.

VI.   TheSchemeStudied

Toreduceenergyconsumptionbutstillimprovedatathroughput ,thepresentedschemeadaptivelyadjuststheactiveperiodbased onthedatatrafficinformation.Thisdescription,usestheterm*sen tinelduration*torefertoaspecialepochfordetectingthetrafficinf ormation.
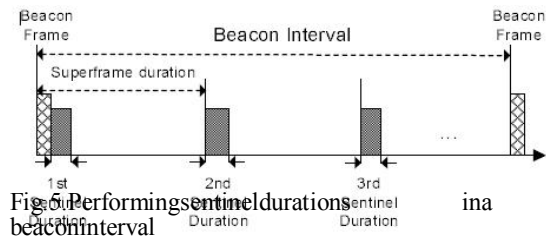

Fig. 5. Performingsentineldurations ina beaconinterval

A. AdaptiveActiveDuration

Inthisscheme,deviceshavingnodatatrafficarenotrequiredtoco ntinuouslymaintainanactivestateevenwhentheyareintheirsup erframedurationpart.Thesentineldurationisperiodicallyperfo rmedwithalengthequivalentto asuperframedurationinasingle beaconintervalasshowninFig.5.Inthisscheme,thevalueforSup erframeOrder(SO) issettobesmallerthantheBeaconOrder(BO).Therefore,severa loccurrencesofsentineldurationcanbeperformedinonebeaconi nterval.Atthestartofasentinelduration,ifanodefindspendingd atatraffic   initsqueue buffer,ittriestoconveythetrafficinformationtoitscoordinator. Ondetectingtrafficpresencefromdevicesatsomesentinel duration,the   coordinatormaintains anactiveRFstateto receivedataframes untilthenextsentinelduration.Ifthereisnodatatrafficatanysenti nelduration,thecoordinatoranddevicescanenterorcontinuousl ymaintainthesleepstateaccordingly.Devicescancontinuously carryoutthesentineldurationsothatthependingdatatrafficscan betransmittedtothecoordinatorevenafterthe superframedurationis   over.Inthis   way,datathroughput canbeincreasedwhiledecreasinglatencywhenthedata trafficloadis high.

B. TrafficIndicationTechnique

This traffic indication technique utilizes the IEEE 802.15.4 CCA function. At the start of a sentinel duration, nodes having data traffic start to transmit it based on the slotted CSMA/CA similar to the original 802.15.4. In order to check the existences of data traffic, our traffic indication technique just waits for general packet frame' s signal during the maximum contention period. The sentinel duration (*TSD*) of traffic indication technique can be calculated as

$$TSD = (2^{BE} - 1) \times aUintBackoffPeriod \quad (1)$$

where *BE* means a back-off exponent value and its maximum value is 5 in the IEEE 802.15.4 standard,

therefore *TSD* is calculated as 620 symbols. As a transmitted packet should appear within the maximum 620 symbols, traffic indication technique can detect existence of the traffic information within this duration. If one of the CCA becomes busy during *TSD*, traffic indication technique decides that there is data traffic. However, if no data is generated during *TSD*, nodes decide that there is no traffic in this active period and enter into the sleep mode. Since our traffic indication technique transmit no additional traffic indicator frames, it is consistent with the original IEEE 802.15.4 MAC without any conflict and control packet transmission overheads.

TABLE II

SCHEMATIC OVERVIEW OF MAC PROTOCOLS IN AWBAN.

MAC-Protocol	IEEE802.15.4 based	TDMA based	CSMA based	Star topology	Time synchronization	Factor improved
Timmons	✓	✓		✓		Power consumption
BSN-MAC	✓	mixed		✓		Energy efficiency, low latency
Lamprinos		✓		✓	✓	Energy efficiency
Omeni		✓		✓		Energy consumption
H-MAC		✓		✓	✓	Network Lifetime
Traffic adaptive	✓	✓		✓	✓	Reducing energy wastage

VI. Current Progress Towards IEEE 802.15.6

Recently, researchers from academia and industry have focused their interest on the development of the IEEE 802.15.6 [9] specification as the future standard for BANs for both medical and non-medical applications, with priority given to medical application data. One of the main technical issues in BAN is the reliable and efficient transfer of vital life signs using wireless communication near the human body, which is a very lossy medium. A key technical requirement is to meet the reliability requirement as set out by the IEEE 802.15.6 draft standard, which states that "the packet error rate (PER) shall be less than or equal to 10% for a 256 octet payload with a link success probability of 95% overall channel conditions". Most research adopts a Star Topology (ST) as the default topology for BANs for simplicity of the communication protocols and to reduce the power consumption associated with multi-hop or Tree Topologies. Project Authorization Request (PAR) presents an extended description of the task group. It stresses the fact that current WPANs do not meet

medical communication guidelines, because of the proximity to human tissue.

- The combined effect of high propagation loss, the limited energy source, and the issue of tissue overheating, justify the deployment of more than one transmission hop for BANs.

Started as a Study Group in 2006 and motivated by the increasing research and industry interest in WBANs, the IEEE Standards Association decided to form the IEEE 802.15 Task Group 6 in November 2007. It describes itself as follows: The IEEE 802.15 Task Group 6 (BAN) is developing a communication standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics and In 2008, a Call for Proposals on physical layer and MAC layer protocols was issued. The large number of responses, 64 in total, confirmed the industry interest. Currently, the responses are being evaluated at monthly meetings, while

some proposalsare merged. The creationof the IEEE 802.15TaskGroup6andtheworkonanIEEE802.15.6 standardstressestheimportanceoftheresearch with respecttoWBANs.

VII. CONCLUSION

AWBANisexpectedtobeaveryusefultechnologywithpotentialtoofferawiderangeofbenefitstopatients,medicalpersonnelandsocietythroughcontinuousmonitoringandearlydetectionof possibleproblems.Inthispaperithasbeenshownthatbyadopting theTrafficAdaptiveMACProtocolinWBANcanresultinthereductionoftheenergyconsumptionofWBAN sensors

.Withthis protocolconsiderationthe wastage ofenergycanbereduced.Futureworkcanbeextendedtomultihopnetworkscenario.

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