CONTENTION-BASED VS. SCHEDULED-BASED WIRELESS SENSOR NETWORK

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Abstract:

In *the area of wireless sensor networks the network is composed of a significant number of nodes deployed in an extensive area in which not all nodes are directly connected. The sensor nodes are generally unattended after their deployment in hazardous, hostile or remote areas. But the thing is that ,"how nodes share the channel" and "how it will work at low energy" are the two main design goal.Contention-based vs. Scheduled-based protocols are used to avoid above problems. In this paper, we present the challenges in the design of the energy efficient protocols and for the wireless sensor network. We describe several Contention-based and Scheduled-based protocols for the WSNs emphasizing their strength and weakness wherever possible. At the end, we discuss the future research directions in the MAC protocol design.*

Keywords— Contention based protocol, Scheduled based protocol, Wireless sensor network

Introduction

Sensor networks are the focus of significant research efforts on account of their diverse applications. A sensor network is comprised of a large number of sensor nodes which collect and process data from a target domain and transmit information back to specific sites. We consider wireless sensor networks which share the same wireless communication channel. But the issue is "how nodes share the channel" and "how it will work at low energy". Medium Access Control (MAC) protocol plays a major role to solve the problem. This falls into two broad classes: contention-based and contention-free. Contention-based MAC protocols are also known as random access protocols, requiring no coordination among the nodes accessing the channel. Colliding nodes back off for a random duration and try to access the channel again. Contention-free MAC protocols. In these protocols, the nodes are following some particular schedule which guarantees collision-free transmission times.

Sensor Network Overview:

The development of wireless sensor networks was motivated by military applications such as battlefield surveillance. They are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation, and traffic control. Each node in a sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. The size of sensor node is very small. The cost of sensor nodes also varies from a few pennies to hundreds of dollars, depending on the size of the sensor network and the complexity of individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth.

The sensor nodes are densely deployed inside the phenomenon. They deploy random and have cooperative capabilities. Usually these devices are small and inexpensive, so that they can be produced and deployed in large numbers, and so their resources in terms of energy, memory, computational speed and bandwidth are severely constrained. There are different Sensors such as pressure, accelerometer, camera, thermal, microphone, etc. They monitor conditions at different locations, such as temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, the presence or absence of certain kinds of objects, mechanical stress levels on attached objects, the current characteristics such as speed, direction and size of an object. Normally these Sensor nodes consist of three components: sensing, processing and communicating. The development of sensor networks requires technologies from three different research areas: sensing, communication, and computing. Thus, combined and separate advancements in each of these areas have driven research in sensor networks. Examples of early sensor networks include the radar networks used in air traffic control. The national power grid, with its many sensors, can be viewed as one large sensor network. These systems were developed with specialized computers and communication capabilities, and before the term ¯sensor networks came into vogue.[1][3][5]

III. Contention -Based Protocols

Contention-based MAC protocols are also known as random access protocols, requiring no coordination among the nodes accessing the channel. Colliding nodes back off for a random duration and try to access the channel again.[3] .Some points to remember-

- Risk of colliding packets is deliberately taken
- Hope: coordination overhead can be saved, resulting in overall improved efficiency
- Mechanisms to handle/reduce probability / impact of collisions required
- Usually, *randomization* used somehow

Various protocols come under this are, MACA, S-MAC, T-MAC, Preamble sampling-MAC

A. MACA

Multiple Access with Collision Avoidance (MACA) is a slotted media access control protocol used in wireless LAN data transmission to avoid collisions caused by the hidden station problem and to simplify exposed station problem.

The basic idea of MACA is a wireless network node makes an announcement before it sends the data frame to inform other nodes to keep silent. When a node wants to transmit, it sends a signal called *Request-To-Send* (RTS) with the length of the data frame to send. If the receiver allows the transmission, it replies the sender a signal called *Clear-To-Send* (CTS) with the length of the frame that is about to receive. Meanwhile, a node that hears RTS should remain silent to avoid conflict with CTS; a node that hears CTS should keep silent until the data transmission is complete.

- Sender B asks receiver C whether C is able to receive a transmission *Request to Send (RTS)*
- Receiver C agrees, sends out a *Clear to Send* (*CTS*)
- Potential interferers overhear either RTS or CTS and know about impending transmission and for how long it will last
- Store this information in a *Network Allocation Vector*
- B sends, C acks

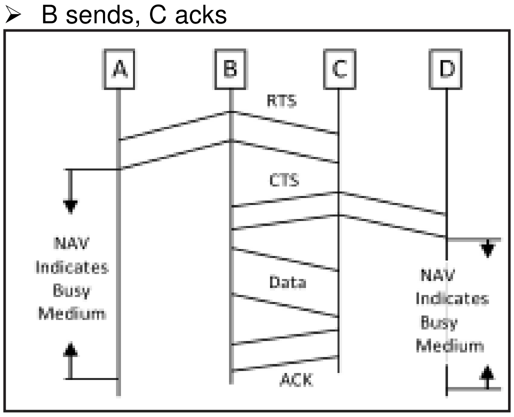


Figure1. Multiple Access with Collision Avoidance

MACA Problem: Idle listening-

- Need to sense carrier for RTS or CTS packets
  - In some form shared by many CSMA variants; but e.g. not by busy tones
  - Simple sleeping will break the protocol
- IEEE 802.11 solution: ATIM windows & sleeping
  - Basic idea: Nodes that have data buffered for receivers send *traffic indicators* at pre-arranged points in time
  - Receivers need to wake up at these points, but can sleep otherwise
- Parameters to adjust in MACA
  - Random delays – how long to wait between listen/transmission attempts?
  - Number of RTS/CTS/ACK re-trials?

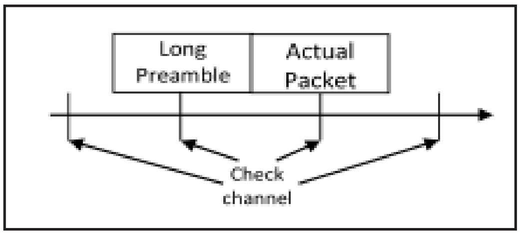
B. Sensor-MAC (S-MAC)

S-MAC, a medium-access control (MAC) protocol designed for wireless sensor networks. Wireless sensor networks use battery-operated computing and sensing devices. Basic concept of SMAC is periodic sleep listen schedules which are handled locally by the sensor network. Nodes which are adjacent form clusters virtually and they share common schedule.

Advantages: The battery utilization is increased implementing sleep schedules. This protocol is simple to implement, long messages can be efficiently transferred using message passing technique.

Disadvantages: RTS/CTS are not used due to which broadcasting which may result in collision. Adaptive listening causes overhearing or idle listening resulting in inefficient battery usage. Since sleep and listen periods are fixed variable traffic load makes the algorithm efficient.

- MACA's idle listening is particularly unsuitable if average data rate is low
- Most of the time, nothing happens



- Idea: Switch nodes off, ensure that neighboring nodes turn on simultaneously to allow packet exchange (rendez-vous).

Figure 2.Process of S-MAC

- Only in these *active periods*, packet exchanges happen
- Need to also exchange wakeup schedule between neighbors
- When awake, essentially perform RTS/ CTS
- Use SYNCH, RTS, CTS phases
- Nodes try to pick up schedule synchronization from neighboring nodes
- If no neighbor found, nodes pick some schedule to start with
- If additional nodes join, some node might learn about two different schedules from different nodes
- "Synchronized islands"
- To bridge this gap, it has to follow both schemes

C. Timeout-MAC (T-MAC)

Timeout T-MAC [7] is the protocol which is derived from S-MAC protocol in which the non sleep and sleep periods are fixed. In TMAC the sensor node deviates to sleep period if no event has occurred for a time

Advantages: TMAC can easily handle variable load due to dynamic sleeping schedule.

Disadvantages: TMAC's major disadvantage is early sleeping problem in which nodes may sleep as per their

activation time and data may get lost especially for long messages. [4][10]

D. Preamble Sampling

Preamble-sampling is a technique used to reduce the energy consumption of the MAC protocol in a wireless node. It provides extremely low energy consumption at low loads and has a notably simple operation and a lack of synchronisation requirements. [1][13] Some points to remember -

- ➢ So far: Periodic sleeping supported by some means to synchronize wake up of nodes to ensure rendez-vous between sender and receiver
- ➢ Alternative option: Don't try to explicitly synchronize nodes
- ➢ Have receiver sleep and only periodically sample the channel
- ➢ Use long preambles to ensure that receiver stays awake to catch actual packet

Example: WiseMAC

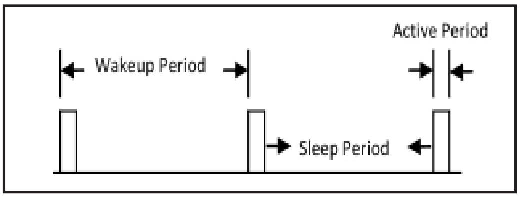


Figure 3. Process of Preamble Sampling

E. B-MAC

It is a carrier sense media access protocol for wireless sensor networks that provides a flexible interface to obtain ultra low power operation, effective collision avoidance, and high channel utilization. To achieve low power operation, B-MAC employs an adaptive preamble sampling scheme to reduce duty cycle and minimize idle listening. [5][8][12]

F. Power Aware Multi-access with Signalling – PAMAS

The protocol is based on the original MACA protocol with the adition of a separate signalling channel. The unique feature of our protocol is that it conserves battery power at nodes by intelligently powering off nodes that are not actively transmitting or receiving packets. The manner in which nodes power themselves off does not influence the delay or throughput characteristics of our protocol. [8][10] Some important points to remember -

- ➢ Idea: combine busy tone with RTS/CTS
  - ➢ Results in detailed overhearing avoidance, does not address idle listening
  - ➢ Uses separate *data* and *control channels*
- ➢ Procedure
  - ➢ Node A transmits RTS on control channel, does not sense channel
  - ➢ Node B receives RTS, sends CTS on control channel if it can receive and does not know about ongoing transmissions
  - ➢ B sends busy tone as it starts to receive data

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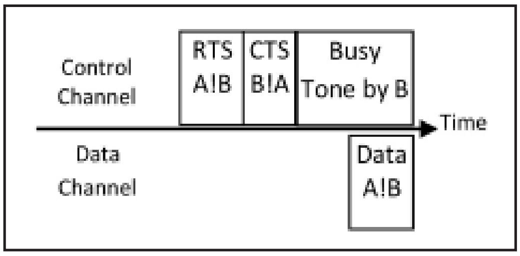


Figure 4. Process of *Power Aware Multi-access with Signalling*

PAMAS – Already ongoing transmission

- ➢ Suppose a node C in vicinity of A is already receiving a packet when A initiates RTS
- ➢ Procedure
  - ➢ A sends RTS to B
  - ➢ C is sending busy tone (as it receives data)
  - ➢ CTS and busy tone collide, A receives no CTS, does not send data

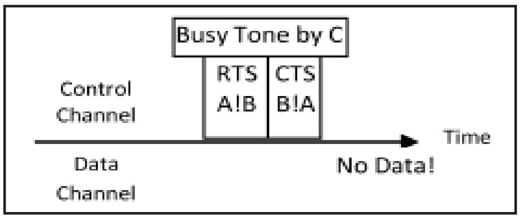


Figure 5. Process of *PAMAS with Ongoing Transmission*

IV. SCHEDULE-BASED MAC

In these protocols, the nodes are following some particular schedule which guarantees collision-free transmission times. [12]

- A *schedule* exists, regulating which participant may use which resource at which time (TDMA component)
- Typical resource: frequency band in a given physical space (with a given code, CDMA)
- Schedule can be *fixed* or computed *on demand*
- Usually: mixed – difference fixed/on demand is one of time scales
- Usually, collisions, overhearing, idle listening no issues
- Needed: time synchronization!

Various protocols comes under this are as - LEACH, SMACS, TRAMA.

A. LEACH

LEACH Protocol is the first protocol of hierarchical
routings which proposed data fusion, it is of milestone significance in clustering routing protocols. Many hierarchical routing protocols are improved ones based on LEACH protocol.The goal of LEACH is to lower the energy consumption required to create and maintain clusters in order to improve the life time of a wireless sensor network.It is self adaptive and self-organized. LEACH protocol uses round as unit, each round is made up of cluster set-up stage and steady-state stage, for the purpose of reducing unnecessary energy costs, the steady state stage must be much longer than the set-up stage. [6][9] The process of it is shown in Figure 1. -10)
Steady-State

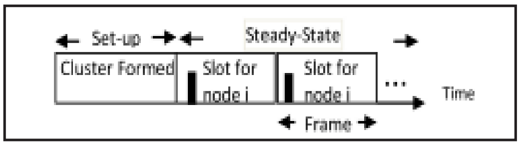


Figure 6. Process of LEACH

B. SMACS

The Self-organizing Medium Access Control for Sensor networks (SMACS) is an infrastructure building
Protocol that forms a flat topology for sensor networks. It is also used as Distributed protocol which enables a collection of nodes to discover their neighbours and establish transmission/ reception schedules for communicating with them without the need for any local or global master nodes.[7][8]

- Given: many radio channels, super frames of known length (not necessarily in phase, but still time synchronization required!)
- Goal: set up directional *links* between neighboring nodes
  - Link: radio channel + time slot at both sender and receiver
  - Free of collisions at receiver
  - Channel picked randomly, slot is searched greedily until a collision-free slot is found
- Receivers sleep and only wake up in their assigned time slots, once per super frame.
- In effect: a local construction of a schedule

SMACS link setup

- Case 1: Node X, Y both so far unconnected
- Node X sends invitation message
- Node Y answers, telling X that is unconnected to any other node
- Node X tells Y to pick slot/frequency for the link
- Node Y sends back the link specification
- Case 2: X has some neighbors, Y not

- Node X will construct link specification and instruct Y to use it (since Y is unattached)
- Case 3: X no neighbors, Y has some
- Y picks link specification
- Case 4: both nodes already have links
- Nodes exchange their schedules and pick free slots/frequencies in mutual agreement

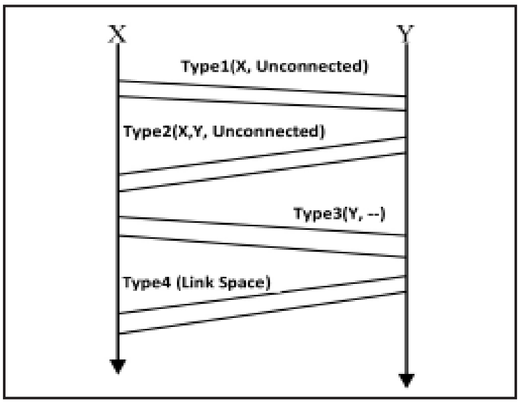
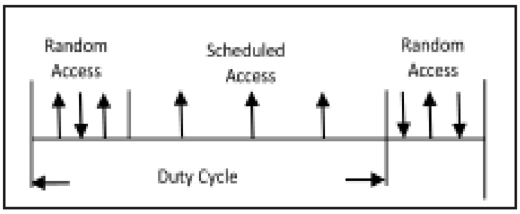


Figure 7.Process of Message Exchange at SMACS

C. TRAMA

In scheduling based protocols, data transmissions are scheduled in advance to avoid contention. However, in such protocols, besides data transmission, nodes exchange neighbor information periodically to schedule the transmission. In TRAMA, contention-free "scheduled access" and contention-based "random access" are performed alternatively. Data transmission is performed in "scheduled access" slot and neighbor information exchange is performed in "random access" slot. The main advantage of TRAMA is improvement in channel utilization. However, the tradeoff is longer delay and higher energy consumption.



The process follows:-

- Nodes are synchronized
- Time divided into cycles, divided into
  - Random access periods
  - Scheduled access periods
- Nodes exchange neighborhood information
  - Learning about their two-hop neighborhood
  - Using *neighborhood exchange protocol*: In random access period, send small, incremental neighborhood update information in randomly selected time slots
- Nodes exchange schedules
  - Using *schedule exchange protocol*
  - Similar to neighborhood exchange

TRAMA – possible conflicts

- When does a node have to receive?
  - Easy case: one-hop neighbor has won a time slot and announced a packet for it
  - But complications exist – compare example

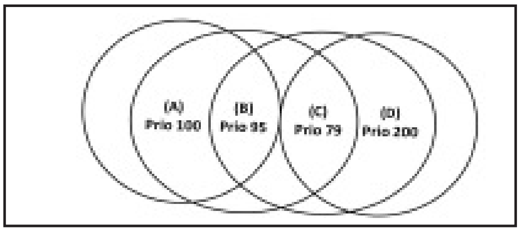


Figure 8. Process of TRAMA

- What does B believe?
  - A thinks it can send
  - B knows that D has higher priority in its 2-hop neighborhood!
- Rules for resolving such conflicts are part of TRAMA

V. CONCLUSION

In case of Schedule-based MAC, A schedule exists, regulating which participant may use which resource at which time. Typical resource: frequency band in a given physical space and Schedule can be fixed or computed on demand (mixed – difference fixed/on demand is one of time scales).Usually, collisions, overhearing, idle listening have no issues and Needed time synchronization! .Where as in case of Contention-based protocols, the Risk of colliding packets is deliberately taken and

Hope for coordination overhead can be saved, resulting in overall improved efficiency. Mechanisms to handle/reduce probability/ impact of collisions required and usually, randomization used somehow.

REFERENCES

1) C. Cano , Author VitaeB. Bellalta ,Author VitaeA. Sfairopoulou Author Vitae,M. Oliver, "*Low energy operation in WSNs: A survey of preamble sampling MAC protocols*" ,Science Direct, *Computer Networks*, Volume 55, Issue 15, Pages 3351-3363, 2011
2) Sanjit Kumar Dash, Subasish Mohapatra, Prasant Kumar Pattnaik, "*A Survey on Applications of Wireless Sensor Network Using Cloud Computing*" International Journal of Computer Science & Emerging Technologies (E-ISSN: 2044-6004) 50 Volume 1, Issue 4, December 2010
3) Costas Busch, Malik Magdon-Ismail,Fikret Sivrikaya, Bulent Yener, "*Contention-Free MAC protocols for Wireless Sensor Networks*" ,DISC 2004,LNCS 3274 pp. 245–259,Springer-verlag, Berlin,Heidelberg,2004
4) Sarika khatarkar, rachana kamble," *Wireless Sensor Network MAC Protocol: SMAC & TMAC*", Indian Journal of Computer Science and Engineering (IJCSE), ISSN: 0976-5166 Vol. 4 No.4 Aug-Sep 2013
5) Joseph Polastre, Jason Hill,David Culler, "*Versatile Low Power Media Access for Wireless Sensor Networks*", SenSys'04, November 3–5, 2004, Baltimore, Maryland, USA
6) Chunyao FU, Zhifang JIANG, Wei WEI, and Ang WEI, "*An Energy Balanced Algorithm of LEACH Protocol in WSN*", IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 1, No 1, January 2013, ISSN (Print): 1694-0784 | ISSN (Online): 1694-0814
7) Katayoun Sohrabi, Jay Gao, Vishal Ailawadhi and Gregory J Pottie, "*Protocols for Self-Organization of a Wireless Sensor Network*" 37th Allerton Conference on Communication, Computing and Control, September 1999
8) Rajesh Yadav, Shirshu Varma, N. Malaviya, "*A Survey of Mac Protocols For Wireless Sensor Networks*", UbiCC Journal, Volume 4, Number 3, August 2009.
9) Jenn-Long Liu, Chinya V. Ravishankar, "*LEACH-GA: Genetic Algorithm-Based Energy-Efficient Adaptive Clustering Protocol for Wireless Sensor Networks*" ,International Journal of Machine Learning and Computing, Vol.1, No. 1, April 2011
10) G.P. HALKES, T. VAN DAM and K.G. LANGENDOEN "*Comparing Energy-Saving MAC Protocols for Wireless Sensor Networks*", Springer Science + Business Media, Inc. Manufactured in The Netherlands, Mobile Networks and Applications 10, 783–791, 2005
11) Venkatesh Rajendran, Katia Obraczka, J.J. GarciaLunaAceves, "*EnergyEfficient, CollisionFree Medium Access Control for Wireless Sensor Networks*", SenSys'03, November 5–7, 2003, Los Angeles, California, USA
12) Bhavana Narain, Anuradha Sharma, Sanjay Kumar and Vinod Patle, "*Energy Efficient Mac Protocols For Wireless Sensor Networks: A Survey*", International Journal of Computer Science & Engineering Survey (IJCSES) Vol.2, No.3, August 2011, DOI: 10.5121/ ijcses.2011.2309
13) Giorgio Corbellini, C´edric Abgrall, "*Emilio Calvanese Strinati, and Andrzej Duda*", Technical Report: Energy Evaluation of Preamble Sampling MAC Protocols for Wireless Sensor Networks", hal-00658371, version 2 - 29 Feb 2012