

A STUDY OF LOW ENERGY TIME SYNCHRONIZATION USING DIFFERENT TYPES OF METHODS IN WIRELESS SENSOR NETWORK

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ABSTRACT

There are many applications available in the Market for wireless network. In this paper, low energy wireless sensor network using in the form of batteries and to minimize the energy consumption by using different Time Synchronization methods and their impact of time synchronization methods for low energy and characteristics of time synchronization methods have given. Wireless sensor networks make particularly extensive use of many different types of Time Synchronization Methods. Each Method has its own functional characteristics. Primary concern of study Low Energy Time Synchronization in wireless sensor network by using Post Facto Synchronization, Reference Broadcast Synchronization, Global positioning System and Network Time Protocols. In this paper these type of Time synchronization methods characteristics and different constraints are used for low energy Time Synchronization in wireless sensor network. XLP Battery Life Estimator estimate battery life time.

Keywords- Embedded Controllers, GPS, NTP, RBS, WINS Platform, XLP

1. Introduction

There are many Time synchronization methods involve in WSN. In this paper Post Facto Synchronization, Reference Broadcast Synchronization, Global positioning System and Network Time Protocols shows their energy consumption for sensors. These methods provide their efficiency regarding low energy consumption in sensor networks. XLP Battery Life Estimator estimate battery life time. XLP Battery Life Estimator is a free software available.

2. Wireless Sensor Networks Characteristics [5]

- It uses low-power
- It consists low-cost
- Unattended
- It consists huge amount
- It is highly distributed
- It also detect ambient conditions
- Small
- Wireless

2.1 Unique requirements

- It has require energy
- It has require lifetime
- It has require time
- It has require precision

3. Time synchronization

Time synchronization algorithms provide a mechanism to synchronize the local clocks of the nodes in the network, global clock or relative to each other [4].

The requirements for synchronization algorithms in Wireless sensor network are more strict due to the different constrains.

- It consists high accuracy
- It consists high precision
- It consists small number of messages
- It consists small impact when we have interference

3.1 Constraints for Time Synchronization in WSNs

- Use of extra hardware (like GPS receivers) is mostly not an option
- Negligible propagation delay between neighboring nodes
- Manual node configuration is not an option
- An algorithm should scale to large networks of unreliable nodes
- Quite diverse precision requirements, from ms to tens of seconds
- low mobility
- Often there are no fixed upper bounds on packet delivery times (due to MAC delays, buffering)

4. Post-Facto Synchronization

Use Post facto Synchronization adopt Application and explore domain knowledge Traditional time synchronization schemes synchronize node clocks a priori; clocks are pre-synchronized when an event occurs and is time-stamped. As we saw earlier, this causes problems with message relaying and makes it hard to exploit time-variable and unpredictable application knowledge. In contrast, we advocate post-facto synchronization, where clocks run unsynchronized at their own natural rates. When timestamps from different clocks need to be compared, they can be

reconciled after the fact This removes the need to predict application requirements in advance; instead, synchronization energy is only expended after an event of interest has occurred. Also, this approach enables support for message relaying, since it does not require network connectivity between event-generating nodes[5,10].

Time synchronization is comparable in some sense to routing in ad hoc networks. There, proactive routing establishes and maintains routes between nodes in advance, whereas reactive routing only establishes routes on demand between pairs of nodes that want to communicate.

4.1 Adapt to the Application

we argued that scalable and energy-efficient WSN time synchronization should be achieved by closely matching the application requirements along axes such as scope, lifetime, and precision. We have also seen a number of techniques that provide service in different parts of this space. However, application requirements vary over time and are in general not predictable, since they depend on the sensed phenomena. Choosing and tuning a necessary and sufficient form of synchronization is a non-trivial problem. The application requirements of time synchronization must be built in at design-time. However, dynamics of the application and the environment are likely to dictate that automatic adaptation at dynamically is also necessary.

In some cases, the application can explicitly describe its requirements to the synchronization subsystem: the precision required, the peers to which synchronization is needed, and so forth. There are also cases where the synchronization subsystem can deduce application requirements implicitly. For example, data flow might imply the scope and lifetime of needed synchronization. Once the requirements are known, synchronization should adapt to them. For example, the number of synchronization packets sent can be varied, trading energy for precision if dictated by the application. The synchronization system might even choose from a set of synchronization algorithms with differing characteristics depending on the application requirements.

4.2 Exploit Domain Knowledge

Much of the design of the Internet—and, in fact, the Internet Protocol (IP) itself—is meant to put a consistent interface on top of a heterogeneous and inconsistent tapestry of underlying transport media and protocols. NTP shares a similar philosophy: it makes a reasonable set of “lowest common denominator” assumptions about the environment in which it expects to operate. In the Internet, this is the right choice: it has allowed NTP to become deployed nearly ubiquitously, despite the wide variety of processors, oscillators, network media, node topologies, and cross-traffic[5,10].

- We know that normally clocks of nodes unsynchronized
- If impulse of event arrives each node records time of impulse with its local time.

4.3 Immediately afterwards

Third party node (beacon) broadcasts synchronization pulse to all nodes in area

- Nodes receive pulse, use it as current time reference
- Nodes normalize timestamps

It is not applicable in all situations

- Instant of synchronized time not practical for sending timestamps over long distance and time limited in scope to transmit range of signal

But adequate in special situations

- Beam forming applications.
- Localization systems.
- Comparing relative arrival time of signal to set of detectors.

5. Network Time Protocol (NTP)

Network Time Protocol (NTP) is a protocol that is used to synchronize computer clock times in a network of computers.

- It was developed by David Mills at the University of Delaware,
- NTP is now an Internet standard. In common with similar protocols,
- NTP uses Coordinated Universal Time (UTC) to synchronize computer clock times to a millisecond,

When calculating the time, an accurate time across a network is important for many reasons; even small fractions of a second can cause problems and shows wrong results. For example, distributed procedures depend on coordinated times to ensure that proper sequences are followed. Security mechanisms depend on coordinated times across the network. File system updates carried out by a number of computers also depend on synchronized clock times. Air traffic control systems provide a graphic illustration of the need for coordinated times, since flight paths require very precise timing (imagine the situation if air traffic controller computer clock times were not synchronized).

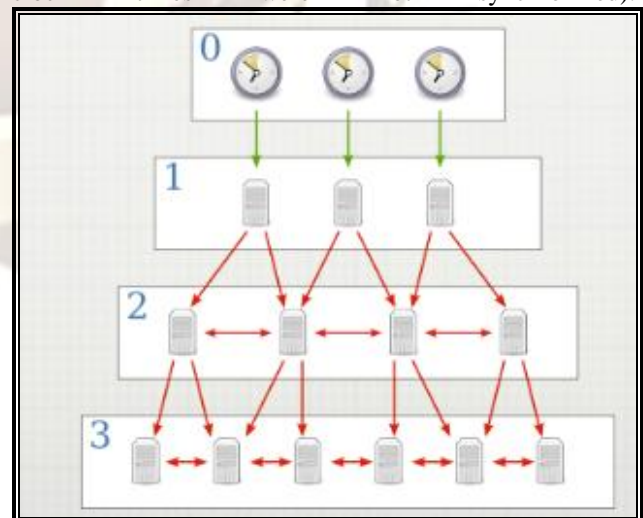


Fig 1. NTP

If very precise timing is not received in that case accidental situation arises.

UTC time is obtained using several different methods, including radio and satellite systems. Specialized receivers are available for high-level services such as the Global Positioning System (GPS) and the governments of some nations. However, it is not practical or cost-effective to equip every computer with one of these receivers. Degrees of separation from the UTC source are defined as strata. A radio signal clock (which receives true time from a dedicated transmitter or satellite navigation system) is stratum-0; a computer that is directly linked to the radio clock is stratum-1; a computer that receives its time from a stratum-1 computer is stratum-2, and so on.

The term NTP applies to both the protocol and the client/server programs that run on computers. The programs are compiled by the user as an NTP client, NTP server, or both. In basic terms, the NTP client initiates a time request exchange with the time server. As a result of this exchange, the client is able to calculate the link delay, its local offset, and adjust its local clock to match the clock at the server's computer. As a rule, six exchanges over a period of about five to 10 minutes are required to initially set the clock. Once synchronized, the client updates the clock about once every 10 minutes, usually requiring only a single message exchange. Redundant servers and varied network paths are used to ensure reliability and accuracy. In addition to client/server synchronization, NTP also supports broadcast synchronization of peer computer clocks. NTP is designed to be highly fault-tolerant and scalable.

The Network Time Protocol (NTP) is an Internet Standard Recommended Protocol for communicating the Coordinated Universal Time (UTC) from special servers called time servers and synchronizing computer clocks on an IP network. (UTC replaced Greenwich Mean Time (GMT) as the international time standard in 1972.)

Time Servers, or time source references, communicate with special time keeping equipment such as Global Positioning System (GPS) receivers, atomic clocks, radios, satellite receivers or modems.

The accuracy of each time server is defined by a number called its stratum. Stratum one servers are those at the top level which communicate directly with a time source such as a GPS or an atomic clock. Each level downwards in the hierarchy is classified as one greater than the preceding level (for example, stratum two, stratum three). Current stratum one servers can provide time within a millisecond's accuracy or better.

This accuracy degrades minuscule as the time message travels through down through the time server strata. The level of degradation varies depending on the time server itself and the network path between the time server and its various clients. In most Internet locations,

NTP is accurate to within 1-50 milliseconds. In practicality of course there is no appreciable difference in the service delivered by stratum one, two or three servers.

NTP will be operate on port 123.

6. Reference Broadcast Synchronization (RBS)

- A Broadcast channel is needed in the network.
- Clients exchange their respective reception times and calculate relative offset and rate differences with other clients.
- Client transforms local time reading into any other client's local timescale.
- A Beacon node is required to sync all its neighboring nodes with one another [2].

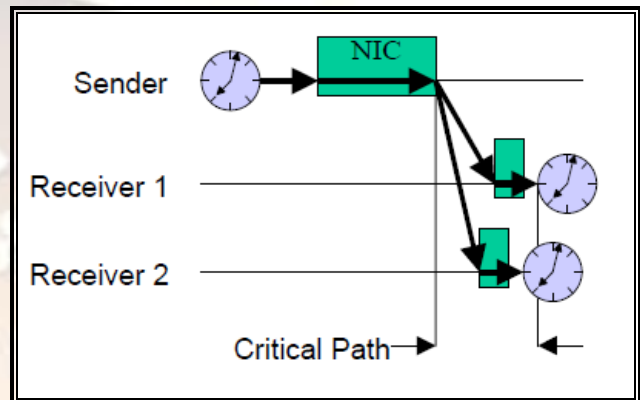


Fig. 2. Shows Reference Broadcast Synchronization

- Beacon nodes time stamp is not needed
- On Demand Synchronization
- It records the past offset calculation when used on demand
- Removes errors due to Send Time and Access Time
- At receiver time stamp can be read at the time of receiving beacon, hence reducing Receive Time Error
- Higher Accuracy then NTP and lower Energy consumption. ($6.29 \pm 6.45 \mu s$, 8 time better then NTP)[3]

6.1 Reference Broadcast Synchronization (RBS) Application [2]

- It can be used in any application where nodes does not need absolute time (UTC).
- It can also be used in Energy saving networks.

7. Global Positioning System (GPS)

GPS is a most widely publicized location-sensing system. GPS is available for all users. GPS has no restrictions or direct charge [5, 6].

- It originally established as NAVSTAR (Navigation Satellite Timing and Ranging)
- This provides framework for determining geographic positions"

- This is only fully operational global navigation satellite system (GNSS)
- It consists of at least 24 satellites orbiting at approx. 11,000 miles
- It started in 1973, fully operational in 1995" Two levels of service:"
- It shows Standard Positioning Service (SPS).
- GPS has high-quality receivers have accuracies of 3m and better horizontally.
- GPS has Precise Positioning Service (PPS).
- GPS used by US and Allied military users.
- GPS is also used in DTC buses in Delhi.
- GPS uses two signals to reduce transmission errors
- Satellites are uniformly distributed in six orbits (4 satellites per orbit).
 - Satellites circle earth twice a day at approx. 7000 miles/hour.
 - At least 8 satellites can be seen simultaneously from almost anywhere.
 - Each satellite broadcasts coded radio waves (pseudorandom code),
- containing
 - It has identity of satellite.
 - It has location of satellite.
 - It has the satellites status.
 - It has data and time when signal was sent.
- It has six monitor stations constantly receive satellite data and forward data to a master control station (MCS).
 - MCS is located near Colorado Springs, Colorado.
- MCS uses the data from monitor stations to compute corrections to the satellites orbital and clock information which are sent back to the satellites.
- Satellites and receivers use accurate and synchronized clocks.
 - Receiver compares generated code with received code to determine the actual code generation time of the satellite.
 - Time difference Δ between code generation time and current time.
 - Δ expresses the travel time of the code from satellite to receiver.
- Radio waves travel at the speed of light (approx. 186,000 miles/second).
- With known Δ , the distance can be determined.
- Receiver knows that it is located somewhere on a sphere centered on the satellite with a radius equal to this distance with three satellites, the location can be narrowed down to two points typically one of these two points can be eliminated easily With four satellites, accurate localization is possible accurate positioning relies on accurate timing receiver clocks are much less accurate than atomic GPS clocks.

GPS small timing errors lead to large position errors. example: clock error of 1ms translates to a position error of 300km. fourth sphere would ideally intersect with all three other spheres in one exact location spheres too

large: reduce them by adjusting the clock (moving it forward) spheres too small: increase them by adjusting the clock (moving it backward) [5,6].

7.1 GPS Advantages

GPS is true within 10m for 90% of all measurements.

7.1.1 Accuracy

10m ("how close is the reading to the ground truth")

7.1.2 Precision

90% ("how consistent are the readings").

- GPS synchronize to persistent lifetime.
- GPS has earth wide in scope.
- GPS precision of 200 ns.

7.2 GPS disadvantages

- It can't be used everywhere.
- It require several minutes to adjust time.
- It is large.
- It uses high power.
- It is expensive.

8. WINS Platform [5]

- WINS platform basis of post-facto synchronization nodes' radios,
- CPU powered down low-power pre processor powered.
- If pre processor detects potentially interesting signal.
- Pre processor powers on CPU further analysis if CPU decides that event needs to be reported CPU turns on node's radio components consuming most energy powered down most time brings up significant problems:

How to achieve accurate timestamps when radio and CPU are turned off most time?

8.1 Low Energy Design

Low energy design considerations for low cost Environmental parameter monitoring wireless sensor network using recent 8-bit embedded controllers PIC16LC74A exhibits very low power operation which is available with options such as internal resources enabled mode and internal resources disabled mode. This ensures the requirement of the situation in which the WSN is being used.

In remote and hostile areas, WSN demands low but continuous power requirement. Hence PIC controllers fulfill such demands without compromising with the quality. It is because of selective conditions of operation, such as sleep mode wherein only required power is drawn from the source to ensure most minimum power consumption and hence power supply unit will have longer life span. Typically, it needs only 0.9 μ A when WDT and external oscillator of Timer 1 is disabled [4].

PIC16LC74A provides another feature such as it needs very low current when its oscillator works at low frequency. For example, when operated at 32 KHz, it draws typical current of 22.5 μ A and maximum current of

48 μA . Such feature is very much required in WSN applications where fast response of the sensors is not required. For example, seismic sensors are slow in response and hence higher execution speed is not required.

Hence, there is a need of slow clock speed thus low power is drawn. Similarly, on chip A/D converter, when enabled but not used, requires only 90 μA . Experimental observations given below are emphasizing on the similar benefits due to the use of recent 8-bit controllers.

8.2 PIC16F193X/194X Microcontrollers

Advanced Performance & Integration with Industry Leading Low Power : 8-bit microcontrollers that can meet the design challenges this creates. This requires microcontrollers that provide increased performance, maximum integration, and the lowest power – the PIC16F193X/194X family does just that[8].

8.3 Key Features

- Integrated LCD Control with up to 184 segments
- Integrated mTouch Capacitive Sensing Module
- Up to (17) 10-bit ADC channels
- Up to 28 KB of Flash Program Memory.
- Up to 1 KB of Data Memory
- 256 bytes of High Endurance Data EEPROM
- 32 MHz internal oscillator
- Up to 3 comparators with Rail-to-Rail input and 555 timer functionality
- Up to 2 each: Master SPI/I2C and EUSART support for RS-232/RS-485, as well as LIN support
- 5-bit DAC providing 32 level voltage reference
 - Easily implemented as a low voltage detect
- Up to 3 Enhanced and 2 Capture Compare PWM
- peripherals with independent time base
- Low Power 'LF' Variants with XLP Technology
 - Dynamic currents down to 50 $\mu\text{A}/\text{MHz}$
 - Sleep currents of 60 nA
 - Watchdog Timer (WDT) current of 500 nA
 - Low-power 32 kHz Timer1 oscillator current of 600 nA
- 1.8V operation up to 5.5V
 - Full analog operation throughout
- 16-level hardware stack, with overflow/underflow interrupt
- 4x8-bit and 1x16-bit timers, with eXtreme Low Power
- Real-Time Clock (RTC) support
- Robust and reliable operational monitors, such as Power-On Reset (POR), Brown-out Reset (BOR) and low-power

8.4 PIC Microcontrollers with nanoWatt XLP Technology[9]

8.5 Development Tools PIC18 Starter Kit PIC18F46J50 Family (DM180021)

- It includes an on-board debugger.
- It has programming capability.
- It has USB communication.
- Board can function as a USB mouse or mass storage device.
- It includes MicroSD™ memory card slot.

8.6 F1 Evaluation Platform

PIC16F1937 Family
(DM164130-1)

- Demonstrations focusing on low power, LCD and motor control
- Provides a platform for general purpose development
- Demonstration/development tool for Enhanced Mid-Range PIC microcontrollers
- Platform consists of a 44-pin development board with prototyping space

As more electronic applications require low power or battery power, energy conservation becomes paramount. Today's applications must consume little power, and in extreme cases, last for 20 years, while running from a battery. Products featuring Microchip's nanoWatt XLP technology extend battery life and reduce standby currents to support green initiatives worldwide.

8.7 PIC® MCUs Offer eXtreme Low Power

- Sleep currents down to 9 nA
- Active Mode currents down to 50 $\mu\text{A}/\text{MHz}$
- Execution Efficiency with more than 80% PIC MCU single cycle instructions
- Execute code smarter, sleep longer, maximize battery life
- Wake-up sources including RTC, WDT, BOR, Interrupts, Reset or POR

8.9 Low Power Peripheral Integration

Many of today's low power products need advanced peripherals. Microchip offers low power devices with peripherals like USB, LCD and mTouch capacitive sensing.

This eliminates the need for additional parts in the application, which saves cost, current and complexity.

8.10 Low Power Reliability

In addition to peripherals, products with nanoWatt XLP have system supervisory circuits specially designed for battery powered products.

- Watchdog Timer down to 200 nA, provides protection against system failure
- Real-time Clock/Calendar down to 450 nA, provides precise timekeeping
- Brown-out Reset down to 45 nA, protects as batteries are depleted or changed

8.11 Battery Life Estimator

The XLP Battery Life Estimator is a free software utility to aid you in developing extreme Low Power applications with Microchip's PIC MCUs featuring XLP technology.

- Profile your application Run and Sleep time (duty cycle)
- Select operating temperature and operating voltage
- Pre-loaded with most common battery specifications

8.12 Featured XLP Product Families

Device Family	Sleep (nA)
PIC16F727	20
PIC16F1829	20
PIC16F1947	60
PIC18F47J13	9
PIC18F47J53	9
PIC18F87K22	20
PIC18F87K90	20

Table 1. XLP Product Families Devices sleep energy down.

CONCLUSION

NTP is accurate to within 1-50 milliseconds. In practicality of course there is no appreciable difference in the service delivered by stratum one, two or three servers. The XLP Battery Life Estimator is a free software utility to aid you in developing extreme Low Power applications with Microchip's PIC MCUs featuring XLP technology. XLP product family PIC18F47J13 and PIC18F47J53 have sleep energy down to 9nA. Active Mode currents down to 50 μ A/MHz. Higher Accuracy then NTP and lower Energy consumption. ($6.29 \pm 6.45 \mu$ s , RBS 8 time better then NTP). GPS precision of 200 ns.

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