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Data Correlation in Sensor Networks

Constantin-Daniel Oancea[1]

[1]*University Politehnica of Bucharest, Bucharest, Romania, daniel.oancea@upb.ro*

***Abstract* –Sensor networks provide a number of benefits by being a group of independent elements that communicate with a central node. Since it has possible that correlate data sensor, the issue of data timestamp become. The paper presents a revise of methods to give timestamp of data from sensor network. Each sensor can provide along its own data, time information, useful when aggregate them. The proposed aim is to compare various technologies, like GPS and DCF77 with their own limits and benefits.**

Keywords – Sensors, Timestamp, GPS, DCF77

I. INTRODUCTION

Network sensors have many applications and can be spread on large area. It is useful in whether forecast, wild animal monitoring ornatural disasters.In urban area, examples of applications are to monitoring parking area, traffic congestion, mechanical stress of bridges and thermal monitoring of power transformer. Some of these are on relatively extensive area. Other examples of sensor networks have health monitoring of a patients and military application [1], [2].

There are two procedures to retrieve data from sensors: on demand or permanent stream. Each one is best suitable to particular applications. The first one is fit when are many sensors and transmit update only after everyone interrogation. A second situation is fit to direct link between sensors and main unit and a constant flow data are changed, [1]-[4].

As element of network, sensors can be places everywhere. In order not to influence the environment in which it works, the sensors must be minimally invasive. Some of sensor networks request data synchronization. Data from source sensor to sink node must be stable and correlated every time, [3], [4].

Data transferred can be ordered or unordered mode. First mode doesn't request data correlation. The unordered data transfer has the following cases: wholesale transfer (all data are transferred to a local host for further processing),timestamp synchronization(all data have timestamps mark) and mathematical synchronization (data have transfer according with a mathematical process). There are many time signaling. Along GPS, systems like WWVB (USA), MSF60 (UK), JJY (Japan), RTZ (Russia), DCF77 (Germany) are widely used to retrieve time information. There are some difference between all these countries specific signaling and worldwide GPS, [5], [6].

II. RELATED ASPECTS IN THE LITERATURE

A. Global Positioning System (GPS)

Global radio navigation system known as the Global Positioning System (GPS) consists of a constellation of 24 satellites and their ground stations. GPS uses a system of specific satellites as reference points to calculate the locations with an accuracy of meters, Fig. 1.

The position is calculated by measuring the distance to at least three satellites. The extra measurement resolves the synchronization errors.The advanced version of GPS (e.g. differential) can make measurements with an accuracy of centimeters. Every satellite have highly accurate real-time clock [5]. Satellite signals reveal more information, suchby the interest to the user, like position and the time.

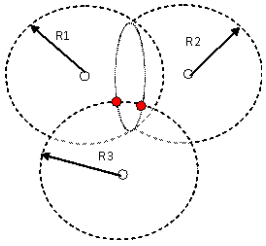

Fig. 1. GPS triangulation principle

Any reasonable GPS device will need four channels (signals from four sattelites) to make a good location.Inherent errors related to syncronisation, disturbance, signal propagation, and so on,are present because ofspecific way of GPS systemoperating [5], [6].

B. DCF77

The official German time signal, DCF77 (D: Germany; C: long wave; F: near Frankfurt; 77: 77.5 kHz) is simple (pulses are 100ms for low bit and 200ms for high bit) and easy to use time signal.

Time base is very accurate because of atomic clocks used [7], [8].Technically, DCF77 signal consist in 59 bits (40 bits are interested to data and time information). Some of these bits are used for error correction (by parity bits, even parity). Time and data are BCD (Binary Coded Decimals) coded, Fig. 2.

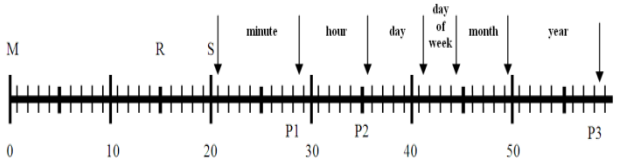

Fig. 2. DCF77 bits sequence

Pulse width modulation is used to reveal "0" (100ms width) or "1" (200ms width) logical state, [8], [9].

Additionally, DCF77 signal contain weather information of some Europe regions and cities (most on west and central Europe), on first 14 bits (usually are ignored). M bit has always "0" logical value and S bit has always "1" logical value. R bit can be "0" or "1" depending from which antenna signal come (DCF77 system have two antennas: one main and one as a reserve, "1"). P1, P2 and P3 are parity bits, [9], [10].

III. DESCRIPTION OF THE TESTING DEVICES

To receive signals, two different devices has used. For GPS a receiver Holux GM-210 can tracks up to 12 satellites at time. Device used have RS-232C interface and additional power adapter, Fig. 3. The GM-210 outputs data in NMEA-0183 format as defined by theNational Marine Electronics Association (NMEA) standard, Table 1.

Fig. 3. GPS receiver Holux GM-210

Table 1. NMEA-0183 message.

	Header NMEA	Description
1	GPGGA	Global positioning system fix data
2	GPGLL	Geographic position- latitude/longitude
3	GPGSA	GNSS DOP and active satellites
4	GPGSV	GNSS satellites in view
5	GPRMC	Recommended minimum specific GNSS data
6	GPVTG	Course over ground and ground speed

For DCF77 time system was used DCF1 receiver from Pollin Electronic GmbH, Fig. 4. Precautions of use are related to the fact that the working time in normal operation can reach 20 minutes and depends by quality of radio signal.

Fig. 4. DCF77 receiver

Another limitation, relatively to this time signal system, has distance from radio antenna. A maximum of 2000km are allowed and this include most of European countries, including Bucharest (about 1500kmin a straight line). Because of long wave radio frequency (77.5 kHz) carrier useful is a ferrite rod antenna.

IV. RESULTS AND DISCUSSIONS

Expected results are related to operating speed, delay startup, time accuracy, ease of use and application development.

GPS signal is complex and contain many information, not only time information, like speed or altitude information. Another benefit is about the presence of the signal, practically all over the world.GPS data can has retrieve by any serial monitor, Fig. 5, or by specific software, Fig. 6, developed in LabVIEW.

Decoding of GPS signal has simple aspects, like string operation, Fig. 5. Information underlined consists in GMT time, local latitude, local longitude and altitude (referenced by sea level). All GPS data are collected in University Politehnica of Bucharest campus, in stationary regime (this is the reason the most of records have "0" value in $GPVTG field; ground speed). The more satellites are in direct visibility with the GPS receiver, the more uncertainty improves.

Geographic coordinates can be in different format (like decimal degrees, degrees-minutes, and degrees-minutes-seconds, UTM, and so on) but GPS use degree-minutes representation. Time information is in UTC (Coordinated Universal Time) standard time.

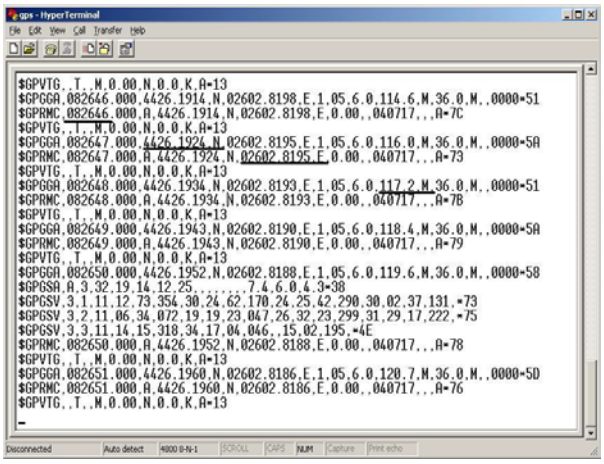

Fig. 5. Example of GPS data

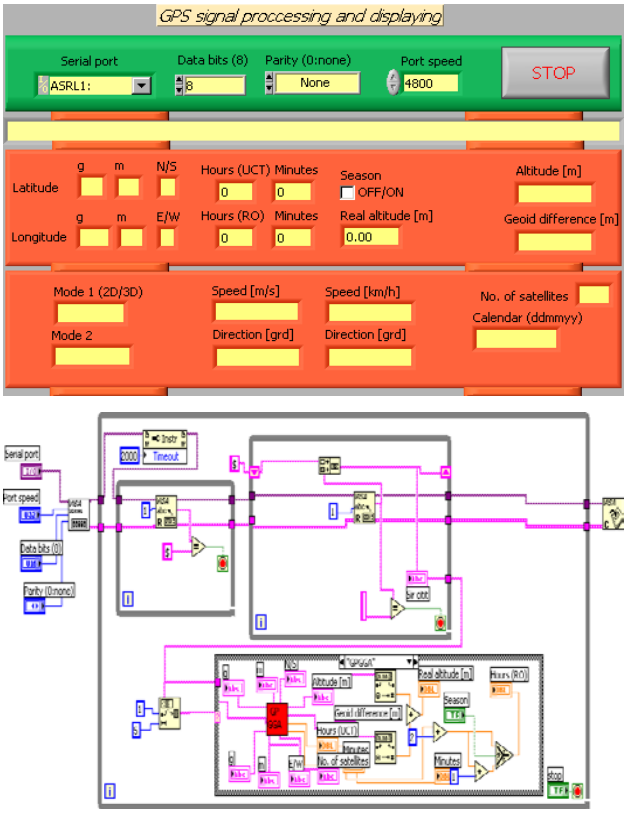

Fig. 6. Front panel (above) and diagram (below) of LabVIEW GPS application (serial reading)

For example, Global Positioning System Fix Data (GPGGA) sequence gives time information and coordinates, Table 2, retrieved from received sample string:
"$GPGGA,082353.000,4426.1730,N,02602.8203,E,1,05, 5.7,98.7,M,36.0,M,,0000*69". This string was decoded by string processing diagram, Fig. 7.

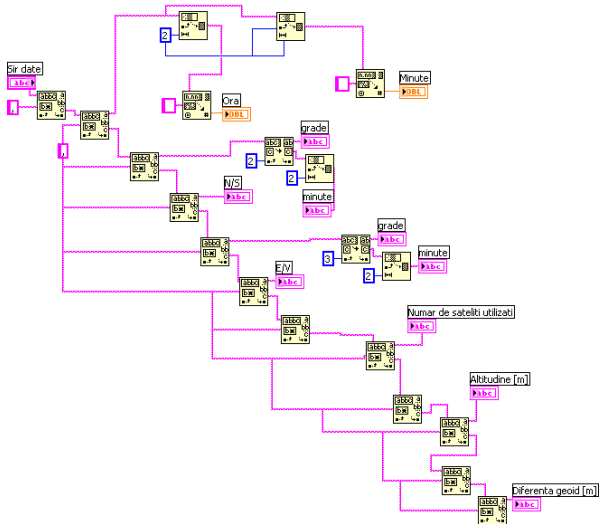

Fig. 7. Diagram of $GPGGA string proccessing

Table 2. GGA Data format (samples).

Name	Example	Description
Message ID	$GPGGA	GGA protocol header
UTC Time	082353.000	hhmmss.sss
Latitude	4426.1730	ddmm.mmmm
N/S Indicator	N	N=North or S=South
Longitude	02602.8203	dddmm.mmmm
E/W Indicator	E	E=East or W=West
Satellites Used	05	Range 0 to 12

GPS date not only provide static quantities, but also have dynamic quantities (speed), in $GPVTG field.Due to civil GPS signal used, experimentally it was found that some data variation. For example, altitude field vary in the same place from 98.7 to 107.1 or 108.1 meters and so on. This is normal because of civil GPS signal intentional uncertainty (civil use).

DCF77 signal has a simple structure, but decoding is more complex then GPS signal, Fig. 8.Application can be developed using special DCF77 designed libraryin conjunction with Arduino timing library.

In tests were used two types of Arduino Board, Arduino Due and Arduno UNO. Main different between boards is the Arduino Due has an accurately clock signal and then is reflected in decoded signal. When use Arduino UNO board, to reveal DCF77 signal and similar application was fine, but to reveal time information not working because of internal clock signal.On both Arduino boards was used digital port to read signal from DCF77 receiver.

A problem with DCF77 signal is noise and interference of radio waves, Fig. 9.Is not actually a far-away problem, but the interferences that may occur in signal propagation by obstructing signal propagation. An appropriate signal would have well-defined block of characters.

The ferrite rod antenna must be positioned carefully and care about near noisy signal sources, Fig. 11.DCF77 signal can be processed by numerical filtering or by removing outliers. Availability of DCF77 signal is guaranteed at 99.7% annually, [10].

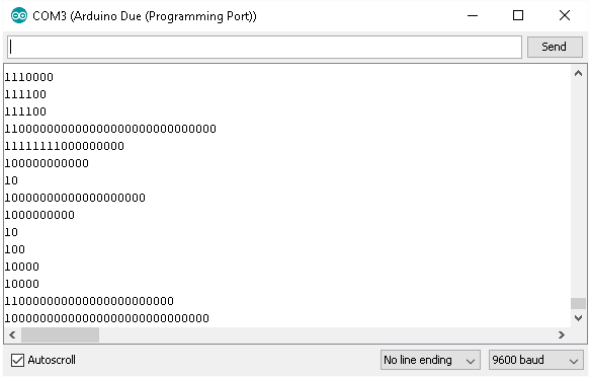

Fig. 8. DCF77 raw signal

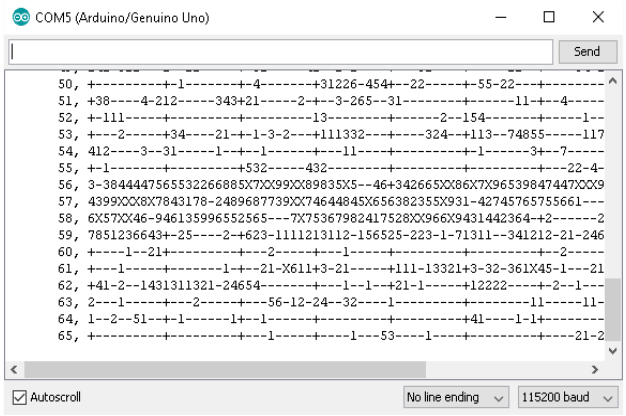

Fig. 9. DCF77 signal (noisy)

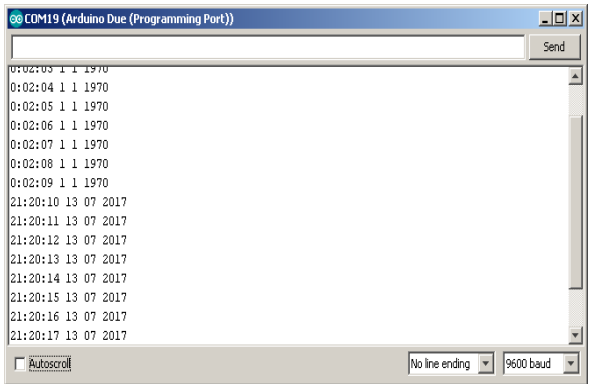

Fig. 10. DCF77 time signal decoded

Fig. 11. DCF experimental components (from left to right Arduino UNO, DCF77 receiver and Arduino DUE)

Additional were test functionality using an antenna (λ/100) and ground but only for test purpose (usually are not necessary; anyway must be used with precautions because can increase dramatically signal noise). The costs of realizing both two devices that provide time information (GPS and DF77) are comparable, with a slight advantage for the DCF77. The complexity of the algorithm is higher for the DCF77 than for the GPS, because in the first case it is necessary to work at the bit level or using libraries.

Startup time of GPS is maximum 2-3 minutes but in DCF77 signal case can reach more than 20 minutes. If GPS signal must have four satellites in direct view to reveal data, the DCF77 need more requests like distance limit from antenna and noise suppression.

Choosing one way or the other to get time depends mainly on the direction of developing the desired complexity, hardware or software.

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