Multi-functional wireless sensor node design for Connected factory

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Acronyms

IoT/IIoT	Internet Of Things/Industrial Internet Of Things
TPMS	Tire Pressure Monitoring Systems
PAN	Personal Area Network
AES	Advanced Encryption Standard
MCU	Microcontroller Unit
I2C	Inter Intergrated Circuit
SM	Sensor Module

1. Introduction

Shifts in industrial automation is rapidly improving due to the advancement in technology and mainly by means of IoT devices. The source of data for any Industrial Automation Solution is through these wireless devices. Often these devices are expensive and challenging with respect to connectivity, security and hence less effective.

Enabling a leading industrial solution provider, such as Utthunga, to provide a low-cost, highly effective, secure solution with lesser time-to-market will benefit both the company and its customers. Hence, a multi-functional, low-power, low-cost, secure, wireless node design is suggested.

This is achieved by having a modular approach. i.e., a fixed wireless design with varying sensor designs. This paper further elaborates on the design. With such an approach, multiple wireless sensor devices such as pressure sensors, light sensors, vibration sensors, temperature sensors, proximity/motion sensors, acoustic/sound sensors can be developed with minimal cost and quicker time to market.

With such wide range of wireless devices, Utthunga will be well equipped to provide better solutions to the Connected Factories. To list a few possible applications:

- Condition monitoring and predictive maintenance of industrial equipment,
- Sound based fault detection in drilling setups and similar,
- Pressure monitoring in pressure critical equipment such as boilers, oil drilling systems, TPMS as part of fleet management, etc.
- Temperature monitoring in pharmaceutical industries, FMCG, etc.

This design approach hence enables us to be an effective end-to-end solution provider for the Connected Factories.

2. Problem/Challenges

A wireless sensor node that are inexpensive and secure are hard to find these days; let alone a multi-functional sensor node. Quite often one node will not meet all the requirements. leading to development of multiple products.

For a manufacturer, this means more inventory and will have overhead with respect to price due to design and development costs. Additionally, time-to-market will be on the higher side.

For a user, this means he will have to use multiple sensor nodes or have to get a customized sensor node designed to suit his requirements. In either case, it will be expensive.

The expectations from the solution can be summarized as follows:

- Develop a secure, low power, low cost wireless modem/transmitter.
- Enable this wireless modem/transmitter to be modular by design so as to attach multiple sensors; which must be interchangeable as and when required by user.

3. Solution

The solution, as summarized earlier, is going to be a two-piece solution.

a. Wireless modem/transmitter

To develop a secure, low power, low cost wireless modem/transmitter, we need to have a platform that supports the following:

- End-to-end AES encryption with keys.
- A PAN with nodes and gateway.
- Low power, which can run on a coin-cell battery for years.
- Multiple data transmission rates.
- Flexibility to change the network topology between star and mesh with minimal development.
- Low cost and available.
- Wireless range being a minimum of 200 meters.

The platform chosen by Utthunga to meet the above requirements is TI's SimpleLink Microcontroller Platform. In addition to meeting all the above requirements, this platform consists of only one MCU which handles the RF and respective protocol, IoT application as well as interfaces to talk to sensors. This makes the development and production less complicated. This indirectly reduces the cost too.

b. Sensor modules

The critical part of this solution is about deciding the right interface to enable the Wireless modem/transmitter to become modular. The interface should be decided based upon the below points:

- Must be a bus based interface to enable multiple sensor modules to be present at once.
- Must have very less number of connections(wires) between the wireless modem/transmitter and the sensor modules. And the number of connections should be same throughout.
- Should support board-to-board communication without any noise.

The interface that is best for this solution is I2C. The advantages of this interface are:

1. This is a bus-based interface and it needs only 4 connections(wires) between the wireless transmitter and the sensor modules. The 4 connections include power lines that run across the bus.
2. It can be connected between multiple boards as long as the distance is very minimal, which is taken care.
3. It is fast enough to transfer data at high speeds when needed.
4. The libraries are readily available, thus reducing the development time.

5. The sensor modules can just consist of a sensor IC which communicates using I2C. This further reduces the cost. Ex: A temperature sensor IC with I2C interface

Disadvantage(s) of choosing this interface are:

1. The sensor modules need to be built with a microcontroller in it, if the sensors are analog or if they have different interface. This can be considered as one of the disadvantages in choosing I2C interface, however it is highly outweighed by the advantages.

To make this design a multi-functional wireless sensor node, we need to have several sensor modules. To name a few:

I. Ambient temperature and humidity module (SM-1)
II. Ambient pressure module (SM-2)
III. Contactless object temperature sensor module (SM-3)
IV. 3-axis vibration module (SM-4)
V. Acoustic module (SM-5)
VI. Gas sensor module ex: Carbon monoxide, etc., (SM-6)
VII. Motion detection module (SM-7)

The sensor module list can continue to grow as and when required.

4. Applications/Case studies

We can look into few applications/case studies where this multi-functional wireless sensor node effectively solves the problem, while comparing other possible solutions using conventional wireless modules.

Application 1: To monitor ambient temperature, humidity and pressure of a chamber in a factory.

[Let us assume, that we need to monitor 10 such chambers in the factory]

1. Approach 1:
   Total number of devices: 2 or more
   a. 1 wireless temperature & humidity sensor node
   b. 1 wireless pressure sensor node

   Pros:
   - In case of failure of one node, the user can still get the sensor data from other node.
   - Can introduce other types of sensors if requirement changes in the field.
   - Time to market is quick.

   Cons:
   - Too many wireless devices in the network.
   - Power to be supplied and maintained for each of these devices.

- Cost borne by the customer will be high since there are multiple wireless nodes.
- Installation and maintenance will be challenging.

2. Approach 2:
   Total number of devices: 1
   a. All in one, integrated wireless sensor node. (Customized)

   Pros:
   - Less number of nodes in the network.
   - Cost effective when mass manufactured.

   Cons:
   - Risk and investment is high when customizing the board to meet specific requirement.
   - Will not be profitable for manufacturer if the requirement is less, as in this case.
   - Time to market is slow.
   - If a requirement to introduce new sensor arises in the field, then it is not possible with this approach.

3. *Our Approach*:
   Total number of devices: 1
   a. One wireless modem.
   b. One pluggable temperature and humidity sensor node.
   c. One pluggable pressure sensor node.

   Pros:
   - Quicker time to market.
   - Less risk and investment as there is no customization.
   - Less expensive for the customer for low to medium scale volumes.
   - Less number of wireless nodes in the network.
   - Can introduce or remove sensors if requirement changes in the field.

   Cons:
   - When the volumes are very high, this approach will not be cost-effective.

Application 2: Predictive maintenance by condition based monitoring for motors.

[Let us assume, that we need to monitor three conditions, viz. Acoustic, Vibration and Temperature]

1. Approach 1:
   Total number of devices: 3
   a. 1 wireless vibration sensor node.
   b. 1 wireless acoustic sensor node.
   c. 1 wireless temperature sensor node.

Pros:

- Each node can be positioned at different locations on the motor as per the requirement from user.
- If there is a need in the future to update the sensors, for example to change the vibration sensor from 1-axis to 3-axis, it is possible.

Cons:

- Too many wireless devices in the network.
- Cost borne by the customer will be high since there are multiple wireless nodes.
- Installation and maintenance will be challenging.
- Power to be supplied and maintained for each of these devices.
- A common MCU can't be considered because, for vibration and acoustic processing, a powerful controller is required, whereas for temperature a simpler MCU can be considered.

2. Approach 2:

   Total number of devices: 1

   a. An integrated wireless device with all three sensors.

Pros:

- Less number of nodes in the network.
- Cost effective when mass manufactured.
- Since customized, a powerful MCU can be chosen at the time of designing to take care of processing audio and vibration sensor data as well as wireless communication.

Cons:

- Not possible to upgrade without redesigning the device.
- Risk and investment is high when customizing the board to meet specific requirement.
- Will not be profitable for manufacturer if the requirement is less
- Time to market is slow.

3. *Our Approach*:

   Total number of devices: 1

   a. One wireless modem.
   b. One pluggable temperature sensor node.
   c. One pluggable vibration sensor node.
   d. One pluggable acoustic sensor node.

Pros:

- Time to market is quicker.
- Less number of nodes in the network.
- Less risk and investment as there is no customization.
- The cost per device for the user will be low if the volumes are low to medium.
- If there is a need in the future to update the sensors, for example to change the vibration sensor from 1-axis to 3-axis, it is easily possible.

- Can choose different MCU for different nodes, as each of them are independent. Ex: Vibration node and acoustic node can have a powerful MCU required for processing, while the temperature node can have no controller at all, as the sensor can directly communicate over I2C.

Cons:

- When the volumes are very high, this approach will not be cost-effective.

As we can see, the proposed solution seems quite effective. But, everything will have advantages and disadvantages. The disadvantage identified for this solution is that it is not suitable for mass production.

So once the product gets streamlined, it is always better to integrate all the sensors onto one board to reduce the cost and for mass manufacturing.

5. Conclusion

In this paper, we have introduced a design approach for a wireless sensor node that is modular in nature. This design approach consists of two main pieces.

- *One which is always present*; a low-cost, low-power, secure wireless modem/transmitter. With the platform chosen (i.e. TI Simplelink), we have also addressed the need for a secure wireless device, which runs on very low power and which provides a very good combination of range and data rate.
- *The other, is a modular piece;* which varies from application to application. With the interface chosen between each boards (i.e. I2C + Power lines) a good amount of pluggable sensor nodes can be added. These nodes can be either with its own MCU or just a simple sensor board.

This is suitable for many different wireless sensor requirements in the industry today. It is applicable for not just industrial requirements but multiple market segments as well.

This will enable us, Utthunga, as a leading industrial solution provider, to build quicker and successful solutions, while also reducing the risk and investment.

6. References

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