Analysis and Assessment of The Quality of Wireless Information Transmission in Shipboard Measurement and Control Systems – Collaborative Perspective

Mostafa Abotaleb

Summary of the Doctoral Dissertation

This doctoral dissertation is mainly concerned about evaluating the quality of using selected types of wireless technologies as a medium for measurement/control data transaction in shipboard systems. Such an evaluation is carried out through a perspective taking into consideration the following key factors:

- Conventional measurement/control systems based on cabling in marine engineering applications are more vulnerable to the negative impact inflected by harsh environmental conditions, than the land based industrial automation systems.
- The utilization of smart sensing techniques can result in an enhanced performance (to a specific extent) of measurement/control tasks executed at shipboard systems.
- Increased levels of reliability and accuracy, easier fault detection and troubleshooting in addition to more efficient maintenance planning are the direct results of the collaborative coexistence between wireless technology, classical cabling-based measurement/control standards and the cabling-based smart sensing protocols.
- Wireless technologies are highly recommended to be deployed as a cooperative data transaction mediums in shipboard systems in order to achieve an optimal improved quality of the conducted measurement /control processes.

Unlike most of the existing previous literature which discussed the various aspects of adopting wireless technology in industrial automation systems, this dissertation is more focused on formulating the outlines of a general strategy, based on which the ships' owners as well as the ships' building facilities can acquire the adequate knowledge required for decision-making process during ships' construction early phases in order to determine the selected techniques (at particular shipboard systems) through which the selected analyzed wireless technologies can be effectively deployed in the most efficient manner. The dissertation concentrates on the possible use of two specific wireless technologies in marine engineering applications. The first technology is the wireless HART protocol as a wireless communication technology dedicated only to industrial applications, while the second technology is Wi-Fi as a general use technology. The analysis conducted in the dissertation is aimed to explore the most efficient way to deploy both technologies in shipboard systems. However, the dissertation will initially dedicate a considerable section to analyze the negative influence of extreme marine environmental/operational conditions on the conventional cabling-based measurement/control systems. Additionally, the dissertation dedicates a significant part to describe the conducted analysis linked to the expected improvement resulted from the utilization of smart sensing technologies such as HART protocol and Foundation Fieldbus in shipboard systems. Conclusively, the dissertation will render the results of the carried out research related to the aforementioned concepts from a point of view affiliated to the aspect of efficient cost saving collaborative coexistence of wireless technologies with other classical and smart sensing technologies in light of the presented theses.

- Conventional shipboard systems based on classical binary/analogue standards are subjected to considerably high levels of temperature, humidity, corrosion, salinity and vibration. The general condition of marine measurement/control systems tends to deteriorate gradually due to the influence imposed by such operational and environmental factors. Such a deterioration can be mostly manifested in ground loops formation and higher levels of capacitive coupling currents, which leads to less accuracy and reliability levels.

Such drawbacks can be overcome to a specific extent by the use of smart sensors based on communication protocols such as HART and Foundation Fieldbus through additional parametric as well as diagnostic information.

- In many cases, the use of wireless technology as a coexistent data transaction medium can provide the solutions for such problems. Improved security of measurement data transaction, facilitated deployment at intrinsically safe applications in explosive hazardous areas are the most important advantages for the deployment of different types of wireless technologies (solely dedicated to industrial automation and general use wireless technologies) in marine engineering measurement/control systems.
- The high density of metallic infrastructure on commercial ships can be an obstructing barrier for the radio frequency RF waves propagation. The proposed techniques in this study will offer the means necessary for improved range capabilities through the collaboration between two protocols (WebSerial and ESP-NOW) in Wi-Fi based applications and the use of adapters and repeaters (methodically positioned through a developed mathematical model) in wireless HART protocol.
- Based on the proposed techniques, wireless technologies such as Wi-Fi and wireless HART will coexist with cabling based shipboard systems in order to implement important principals such as functional safety and predictive maintenance PdM through adopting economically efficient plans.

These theses were successfully validated to a particular considerable degree through a built up strategy aimed to deploy the selected wireless technologies as integrative cooperative data transaction mediums with cabling. The supporting pillars of such a strategy are the major results procured from the executed experimental, simulation-based and real-time analysis, which included:

- Discussing the effects of high levels of temperature, humidity and salinity (major features at marine environment) on cabling-based measurement/control system.
- Analyzing the simulated effect of combined humidity and vibration (another major feature at marine environment) on the smart HART 4-20 mA measurement current loop
- Developing the necessary techniques to avoid the effect of Additive White Gaussian Noise (AWGN) in Foundation Fieldbus protocol.
- Comparison between the different possibilities of deploying FF protocol in a shipboard system such as tank level measurement system (simulation based case study) in safe areas as well as in explosive hazardous areas.
- Implementation of mathematical model dedicated to wireless HART network reinforcement through providing the required methods to indicate the suggested positions of added repeaters and adapters to the network .
- Introducing two planning examples for the wireless HART protocol possible deployment on commercial ships in engine room as well as on deck.
- Introducing improved range capabilities of Wi-Fi as a data transaction medium through the proposed verified and real-time tested techniques based on the cooperation between the WebSerial remote serial monitor and the ESP-NOW protocol.
- Highlighting the most important advantages of adopting the introduced strategy to deploy Wireless HART and Wi-Fi at shipboard systems. The major advantage of such a strategy is the cost effective functionally safe engagement of the selected analyzed wireless technologies in marine engineering, leading to longer service lifetime of the shipboard equipment due to adopting maintenance plans based on predictive maintenance and not only preventive maintenance.