

Chapter 20

Micro–Electromechanical Systems for Underwater Environments

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ABSTRACT

Underwater networking technologies have brought us unforeseen ways to explore the unexplored aquatic environment and this way provided us with a large number of different kinds of applications for environmental, scientific, commercial, and military purposes. Although precise and continuous aquatic environment monitoring capability is highly important for various underwater applications, due to the unique characteristics of underwater networks such as low communication bandwidth, high error rate, node mobility, large propagation delay, and harsh underwater environmental conditions, existing solutions cannot be applied directly to underwater networks. Therefore, new solutions considering the unique features of underwater environment are highly demanded. In this chapter, the authors mainly focus on the use of wireless micro-electromechanical systems for underwater networks and present its advantages. In addition, the authors investigate the challenges and open research issues of wireless MEMS to provide an insight into future research opportunities.

INTRODUCTION

Thanks to Underwater Networks (UNs), the desire and significant interest in monitoring aquatic environments are satisfied. UNs are used for various applications requiring precise and continuous data transfers including oceanographic data collection, pollution monitoring, scientific exploration, commercial exploitation, and coastline protection (Akyildiz, Pompili, & Melodia, 2005; Erol-Kantarci, Mouftah, & Oktug, 2010; Erol-Kantarci, Mouftah, & Oktug, 2011; Ren & Cheng, 2010; Han, Zhang, Shu, & Rodrigues, 2015). Although UNs and ground communication networks have common properties, they

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have two distinct differences. First and foremost, radio communications do not work well under the water and hence they are replaced by acoustic communications (Heidemann, Stojanovic, & Zorzi, 2011;

Akkaya & Newell, 2009). Second, although most ground nodes are static, underwater nodes are mostly mobile since they may move with water currents, waves, and other underwater activities (Heidemann, Stojanovic, & Zorzi, 2011).

Micro-Electromechanical Systems (MEMS) is a rapidly growing, innovative technology which combines micro computers with various tiny mechanical devices such as sensors, actuators, valves, gears, mirrors, and other parts in semiconductor chips. Basically, MEMS devices contain micro-circuitry on tiny silicon chips into which mechanical devices have been manufactured. MEMS is a foundational technology at the present and will continue to be so into the next decade; this technology has already successfully replaced many other devices in several applications since MEMS devices are built in large quantities at low cost and thereby are cost-effective for many uses.

Recently, the use of wireless MEMS in UNs has emerged as a powerful, reliable and low cost technique for many UN applications addressing monitoring, measurement, control, and surveillance needs (Yu, Ou, Zhang, Zhang, & Li, 2009; Chaimanonart & Young, 2006; Sarisaray-Boluk, Gungor, Baydere, & Harmanici, 2011). Due to the significant differences and unique features of UNs, this has received unprecedented interest, although the idea of applying wireless MEMS into monitoring and/or control applications is not new.

MEMS are miniature devices, which integrate processors, sensors, and actuators and their functional subsystems could be electronic, mechanical, optical, fluidic, or thermal. MEMS technology has numerous attributes, which can mitigate challenges to meet future military and non-military application requirements. For instance, MEMS allows miniaturization, reduced cost of fabrication through the use of micro-electronics processing technologies, real-time control, and control of macro physical processes through micro action. Specifically, MEMS can enable enhanced functionality for the following applications:

- Inter-linked communication channels (radio frequency (RF) or optical);
- Optical devices and systems, and displays;
- Micro-satellite and unmanned surveillance systems;
- Multi-sensing capabilities; distributed, agent-based, or sensor array systems;
- Inertial Navigation Systems (INSS);
- Autonomous, unmanned ground sensors, detection and treatment systems
- Intelligent/unmanned operations;
- Power generators and management;
- Integrated fluidic systems including fluid sensing, control & transport;
- Nuclear and bio/chemical sensing;
- Micro thrusters;
- Fuze/safety & arming;
- Health monitoring and utilization monitoring systems;
- Logistic tagging systems;
- Self assembly/healing and reusable modules/subsystems.

The abovementioned generic, functional elements can be integrated across the various platforms for land, sea, air, space and missile applications. Also, as well as underwater vehicles, MEMS can enable the realization of advanced platforms for avionics and aircraft systems, miniaturised spacecraft, smart

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