Smart plankton: a new generation of underwater wireless sensor network

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The aquatic world, which covers more than the 70% of the earth, has been largely unaffected by the WSN revolution (ignited by DARPA funded UC Berkeley “Smart Dust” project) due to the difficulty of transferring most of the knowhow, developed for terrestrial and aerial systems and devices, to their underwater counterparts. Nowadays underwater wireless networks are expensive (US$ 10k or more), sparsely deployed (a few nodes, placed kilometers apart), typically communicating directly to a base-station or sometimes based on the use of underwater manned or unmanned vehicles. Our research is aimed to develop a new generation of UWSN (Underwater Wireless Sensor Network), called Smart Plankton, by drawing inspiration from marine biology and aquatic micro-organism such as zooplankton and phytoplankton. Our target is to develop a self-organizing network composed by a relatively large number of innovative nodes, equipped with sensors for monitoring, surveillance, underwater control and many others potential applications. Inspired to the rich inventory of plankton adaptations our research is oriented to explore innovative solutions in following areas:

1. implementation of the single network node focusing on:

a)the use of reconfigurable architecture, balancing the need of computation (sense, communicate, etc.) with the survivability constraints (energy foraging and storage), with algorithms recently developed for computational embedded intelligence (e.g. kernel methods for embedded and pervasive systems [D. Anguita, A. Ghio and S. Pischiutta, Adaptive Hardware and Systems, p.571, 2007]) for acquiring or improving intelligent behavior;

b)a mobility system based on body thermal expansion of solids and liquids and compression under pressure, such as in sperm whale which uses spermaceti, a semi-liquid, waxy substance for movement and stability;

2. communication between nodes because, in comparison with ground-based sensor networks, mobile UWSNs cannot employ radio frequency (RF). The alternative and more innovative method of optical communication, suggested also by the natural world (e.g. quorum sensing through bioluminescence in plankton shoals [F.J.Jochem, Marine Biology, Vol. 135, p.721]), can allow the development of a high rate, low power, long life and low cost communication link among devices. At our Department, we are testing the use of LEDs and phototransistors for developing an underwater optical communication system (based on 802.11a protocol) considering that experimental tests have shown that the better wavelength lies around 420 nm (blue-violet wavelengths) and that the value changes in presence of turbidity;

3. energy scavenging in order to allow a long life to the network; energy can be generated by using electrochemically active bacteria [B.E.Logan and J.M.Regan, Environmental Science and Technology, 40, p. 5172] which have been recently discovered and have the property to oxidize organic matter and release the electron to an electrode. This has some definite advantages over the use of a chemical catalyst, as bacteria can sustain themselves and recover after inadvertent poisoning;

4. shoal intelligence in order to allow Smart Plankton to perform complex tasks by cooperation of the individuals; this approach can be considered as an application of Swarm Intelligence model [G. Beni and J. Wang, Proceed. NATO Advanced Workshop on Robots and Biological Systems, 1989] for dealing with the peculiarities of the harsh underwater environment.