The Physical Layer of Ambient Intelligence

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During the 20th century, we have witnessed the invention of ever better appliances for entertainment and work, with ever more powerful digital signal processing, transmission, and data storage. Performance metrics in computing, communication, memory, and data storage have all followed Moore's type laws, which still continue into the next decade. New types of displays have been developed, with LCD emerging as the current winning technology, promising to wipe out the cathode ray tube. In fact, we are reaching the point where the quality of a display, an audio set, a digital video recorder, a mobile phone, or of a PC are all so impressive, that one could argue that "good is good enough". Sadly, whenever such a point has been reached, appliances tend to become commodities, difficult to make money with.

A new vision is emerging, where progress is no longer seen as ever better performance of existing functionality but rather an *ambient intelligent* world where the digital environment is sensitive and responsive to people. This vision requires electronic functions that are seamlessly integrated: smart self-configuring networks of appliances, wearable electronics, artificial intelligence, and new user interface functionality will be required. Studies of human behaviour will have to reveal whether people actually like to give orders to a picture on the wall, whether they would like to have their friends being "telepresent" while they are watching a soccer game in the living room. Philips Research has recently opened a dedicated "Home Lab" where such questions are being addressed.

Clearly, a new physical layer that relies on new technologies will be required, such as flexible, paper-like displays and interfaces integrated into garments or furniture. Extreme *miniaturization* beyond the mainstream system-on-a-chip technology, will be a key factor.

Microsystems can also offer *new functionalities*. For example, acoustic MEMS microphones and loudspeaker arrays with dedicated DSP, will enable adaptive directional acoustic systems for the suppression of background noise, speech recognition and directed speech output. Another example is biosensors, which can be applied for water, food, or air quality assurance, or for non-invasive measurement of human parameters for wearable electronics..

Energy supply remains a limiting factor. Progress in the energy storage capacity of batteries lags far behind the above-discussed digital technologies. The ultimate challenge in the field of micro-systems is to invent technologies for smart and *autonomous* micro-systems, which are battery-free, and which take their energy from the environment (visible or rf radiation, thermal gradients, vibration …). This is called energy scavenging. Such micro-systems will also be fitted with sensor and communication functions. Various research laboratories have begun to study the design and system requirements for networks of such smart and autonomous micro-devices that operate in a collective and autonomous fashion. The realization of such "electronic dust" will be essential to make the vision of ambient intelligence come true.