Creating the Smart House

A White Paper on Issues Relating to the Design and Implementation of Smart Houses

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The Archimedes Project is studying smart houses as part of a larger topic of "Human Centered Interfaces to Ubiquitous Computers." Our research strongly suggests that the success of smart houses will depend on the creation of *Intelligent Environments* that embody the following three components:

1. A smart infrastructure that adheres to widely accepted standards
2. Smart appliances from many manufacturers that adhere to these standards
3. Human-Centered Interfaces that automatically adapt to the needs of individual users.

A Smart Infrastructure is the foundation upon which an *Intelligent Environment* is built. It has three primary components: (i) connectivity to local information and physical resources, (ii) connectivity to global resources, and (iii) standardized communications. Most of the operations performed by the smart infrastructure are invisible to the user.

Smart Information Appliances and Smart Physical Appliances perform functions that are useful to the occupants of the smart house. Each smart device must have sufficient intelligence and local knowledge to perform the intended task perfectly. It must also have capabilities for accessing local and global resources and collaborating with other smart devices via the *Intelligent Environment.*

Human Centered Interfaces accept inputs from and provide feedback to the occupants of the smart house in a variety of forms that closely match individual needs, abilities and preferences. It is essential for the system to recognize that different occupants have different profiles and that these profiles change on both a short-term and long-term basis. Three different human interface concepts must be smoothly integrated to provide access to the *Intelligent Environment*:

- ***Interfaces that are built into the infrastructure of the smart house***. These must be smart enough to adapt to the needs, abilities and preferences of the intended range of individual users and must be simple and intuitive to operate.
- ***Interfaces that are built into appliances.*** These must be sufficiently smart to adapt to the abilities and preferences of all potential users. The behavior of the interfaces should support downloadable upgrades to incorporate interface improvements that occur during the lifetime of the appliance.
- ***Interfaces that are provided by the user***. These support personal interaction with all functions and capabilities of the smart house. They range from very simple interfaces through to highly sophisticated smart wearables customized to a particular user.

Interfaces that are "hard-wired" into the infrastructure of the house must be very simple and intuitive to prevent forced obsolescence. It is critical that the occupants are free to choose appliances and interfaces that best match their individual needs, abilities, and preferences. Factors such as culture, education and tradition will also influence the choice of interfaces and the preferred behavior of the smart house.

Conceptual Model

The conceptual model for the smart house developed by the Archimedes Project balances the need for both collaborative and competitive manufacturing and marketing of smart house components. This model defines a clear separation between the infrastructure, which must be long-lived, and the more dynamic parts that interact with the users and the environment. The infrastructure supports the concept of "ageless components" whereby old and new appliances, tools, and interfaces can be mixed in any manner and can be easily added or removed at any time. The concept of ageless components provides many advantages:

- It is easy to customize a house to individual needs, abilities, and preferences.
- The house can be made smarter in an incremental manner since smart components can be added to the house when needed or when the occupant can afford them, while still maintaining full functionality for what is already there.
- People can easily take the "personality" of the house with them when they move the smart components to a new location.
- It prevents forced obsolescence of the components as different versions of products are introduced. In other words, it will ensure that the current computer industry model of manipulating the operating system to make older products unusable doesn't become part of the smart house paradigm.
- Maintenance is simpler because it is no longer necessary for replacements to be identical to the component being replaced.
- Cultural and language differences are easily bridged.
- It will reduce construction costs by simplifying the infrastructure.

Implementation Notes

Conceptually, a construction company should be able to build a complex containing hundreds of functionally identical apartments, each containing the same smart infrastructure. As each apartment is occupied, it will acquire a totally different set of capabilities and personalities depending on the appliances installed by the user.

It is absolutely essential that the infrastructure and the functional interfaces to it are standardized and long-lived. Knowledge bases, data structures, communication protocols, resource management and plug-and-play strategies must be included in the infrastructure and must be totally independent of the underlying transport medium. The only way to achieve this will be through industry-wide collaboration and the development of open standards. The infrastructure must inspire trust and confidence in both the industry and the potential occupant's for the smart house concept to succeed.

A properly standardized infrastructure will lead to a thriving and competitive market for smart appliances. The only essential requirement for smart appliances is that they implement the standardized communication protocol defined for the infrastructure. However, there will be many advantages for manufacturers who fully utilize the resources provided by the infrastructure.

Knowledge – *The "smart" part of the smart house*

In our model, knowledge about the house and its occupants is distributed throughout the infrastructure and the smart appliances and tools. Global knowledge, stored and managed

by the infrastructure, contains details about the particular installation, what resources are available from within and from outside of the house, information on how to handle factors related to location, language and culture, and information about the occupants and the ways in which they use the various resources and tools. Local knowledge is contained in each of the smart components in the house. The knowledge bases must be dynamic, recognizing factors such as: differences due to location, country, or culture, different occupants at different times, short-term visitors, families moving, children growing up, parents getting older and pets coming and going,

Research

There are many areas of research that should be undertaken as soon as possible. Topics to be investigated include:

- **Identifying research and development that has been done already:** many different groups have researched different aspects of smart houses, usually for quite different reasons. A great deal can be learned from a study of previous research particularly with respect to assessing what worked and what didn't work.
- **Understanding the intentions and motives of the developers:** many of the current smart house developments are promoted by companies with specific goals matched to their products or needs: power companies, for example, developing energy management within houses to facilitate demand-side control of their power generation and distribution systems.
- **Understanding the needs and preferences of the consumers:** It is essential that smart houses evolve to meet the needs of consumers rather than being driven by the technology.
- **Comparing the various models that exist for smart houses:** There are at least three extreme models in current implementations: (i) information furnace -- centralized control of all components and services, (ii) transported office model with a PC in every room, and (iii) distributed intelligence -- intelligence is distributed throughout the infrastructure and the smart components. Each component has the intelligence to do the intended task and the ability to collaborate with other devices.
- **Understanding the business model.** No matter how advanced the technology, the smart house will not be successful unless the various players can make money. Potential players include: construction industry, manufacturers of smart appliances and smart wearables, utilities providers, service industry, security industry, insurance companies, financial institutions. Tenants also figure in this equation. In spite of potentially higher initial capital outlay, they will benefit from reduced costs resulting from better managed utilities, lower maintenance, reduced costs for insurance, lower deductibles, and improved security services. Many of the potential cost savings are tightly linked to each other. For example, initiatives such as the million solar roof program are more likely to succeed when the house has a highly efficient energy management capability.
- **Developing the underlying design structures for the smart house:** At present, individual companies are creating proprietary versions of a smart house with the goal of promoting their own products and agencies are promoting technologies that save a particular resource. It is essential that we have a model that bridges the needs for companies to be able to supply proprietary products, for agencies to conserve

resources and consumers to have free choice. Research is needed to identify priorities that provide the greatest savings or results for all players. Common standards are at the core of this equation.

- **Developing Human-Centered Interfaces:** The house offers new challenges for providing fast, intuitive, reliable, and easy-to-learn interfaces between people and the smart components of the house. Interface models and research transplanted from the office or industrial job-site are not adequate for a home environment given the wide disparity of people and processes.
- **Developing standards:** All successful areas of manufacturing revolve around industry-wide standards. Such standards have yet to be developed for the smart house. Standards are evolving in certain parts of the smart house model, the major home entertainment manufacturers, for example, have adopted FireWire to distribute audio, video and control signals among entertainment equipment. It is unlikely, however, that FireWire is an appropriate vehicle for controlling heating and ventilating equipment. While many companies are now developing proprietary standards for networking houses, it is essential that widely-accepted standards are developed at a higher level than the underlying networking medium, i.e., at the protocol level.

Conclusions

Smart houses have the potential to provide many benefits to society: improved use of resources for both construction and ongoing maintenance, lower utility costs, better living conditions, greater security and reduced support costs at many levels. Before they become widely accepted, however, there must be a viable business model supported by industry-wide standards. Much of the existing knowledge has resulted from industry-supported pilot demonstrations designed to show off specific proprietary products. To move forward, it will be necessary to have access to vendor-independent funding to define the core technologies, common standards, and the business model that will lead to widespread viability and acceptance.

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