The Evolution of Architecture
The Potential Impact of the Internet of Things on Architecture

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This paper will propose a succinct and encompassing description of the major elements of the Internet of Things, and how they may interrelate. From this I will explore how the Internet of things may shape the future of architecture.

The term internet of things has no consistent meaning, being frequently used to characterize a product, process or activity, and its utilization of external information. To facilitate this discussion, I will offer a summary description of many of the major intelligent nodes that collectively connected represent the internet of things. These nodes include: smart community, smart-connected vehicles, smart grid, smart infrastructure, cloud processing and storage, etc. For this paper, the term “smart” shall mean the ability to quickly collect and structure information and, in doing so, derive knowledge to make correct decisions.

Smart (Intelligent) Nodes

A smart grid is a modernized electrical grid that uses analog or digital information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers of energy, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity.

A smart, connected vehicle has bidirectional wireless connectivity primarily through four communication protocols:
- Cellular services for communications, diagnostics and app support
- WiFi for app support, data exchange and communications,
- Satellite for GPS navigation and infotainment services such as radio, and
- Dedicated Short Range Communications (DSRC) to send and receive road, weather and traffic information to the other vehicles and infrastructure.

A smart city uses digital technologies to enhance performance and citizen’s wellbeing, to reduce costs and resource consumption, and to engage more effectively and actively with its citizens. Key ‘smart’ sectors in a smart city include transport, energy, health care, education, infrastructure maintenance, water and waste management and others. A smart city should be able to respond faster to the challenges presented from internal and external sources, than one with a simple 'transactional' relationship with its citizens.

Smart infrastructure incorporates sensing technology, allowing for the infrastructure to have the capability to interact with the environment by using real-time data to analyze information received. This would mean being able to respond to the needs of the users and adjust accordingly without the help of a human.

Cloud processing and storage - Cloud computing metaphor: For a user, the network elements representing the provider-rendered services are invisible, as if obscured by a cloud. Cloud computing relies on sharing of resources to achieve coherence and economies of scale, similar
to a utility (like the electric grid) over a network. At the foundation of cloud computing is the broader concept of converged infrastructure and shared services.

With these given definitions, I will proceed to talk about how these nodes interact with each other as well as their integration into society.

**The synergy effect**

Aside from the nodes advancing their efficiency and effectiveness within their boundaries, there are obvious relationships between elements. The most obvious relationship would be between the smart city and the smart grid. As described by [https://www.navigantresearch.com/blog/why-smart-cities-need-smart-grids](https://www.navigantresearch.com/blog/why-smart-cities-need-smart-grids), the smart grid plays a crucial role for a smart city. With my definition of a smart city as the ability to enhance the performance of the city and citizen’s well-being, naturally, the smart grid falls into play. With the smart grid’s ability to obtain various information from within the city, the two nodes, smart infrastructure and smart vehicles, are what the grid will most heavily rely on. Information collected from vehicles could help the smart grid communicate traffic flow to smart infrastructure such as stop lights to better regulate traffic and increase efficiency. In fact some cities that are headed in the direction of being a smart city have already implemented and begun to utilize the smart grid. This can be seen in Detroit, where street lamps (smart infrastructure) have become connected to the smart grid. With the smart grid collecting information such as amount of daylight, the grid can then communicate with the streets lamps to tell them to turn on, off, or even dim. Although streets lamps are a simple example of what the grid could do, there are many other possibilities the grid could provide society.

Another example of two nodes interacting is the communication between the smart vehicle and the smart grid. With the ability of the smart grid to collect and distribute information, the grid could have the potential to coordinate recharging for electric and hybrid vehicles. The last thing the grid needs is for 50,000 rechargeable cars coming into the city for work, each wanting to recharge their vehicle during peak loads. If the car, not necessarily the driver, could communicate when it would need the vehicle next and how much charge would need, the grid could potentially suck out the power that’s in the car and use it and replenish the car before it’s needed, possibly at preferential rates. If the car won’t communicate with the grid, then rates could be substantial higher. Additionally, the grid could inform the car where available charging space facilities are and whether those are slow charge of fast charge, in the proximity of where the owner is or would be going.

The smart grid and smart city is another relationship that could change how things have traditionally been handled. One plausible situation is the smart grid having the ability to send information to the city about the usage of electricity and water. This could enable the city to meet a certain quota, and regulate where to provide said resources as needed.

The relationship between a smart vehicle and a smart city could be the city sending smart vehicles information such as detours for when events like festivals, concerts, sporting events, or when heavy construction is occurring. With this knowledge, and automatically from one’s vehicle, a more efficient route could be planned, saving the driver’s time, and avoiding congestion in traffic and locating available parking.
Factors that will accelerate advances in and between the Smart nodes include increased speed and bandwidth of communications, increased computer processing power and increasing deployment of artificial intelligence.

Communications. The current deployment of LTE-A cellular communications allows a throughput of over 225,000 kbps. Fifth Generation (5G) will have the ability to transmit 50 Gbps, with enough bandwidth and speed to allow you to download a full length movie in less than 3 seconds.

Computing Power - Engineers have developed an ultracompact beam splitter for dividing light waves into two separate channels of information that allows an increase of speed by a million times. The device brings the world closer to producing silicon photonic chips that compute and shuttle data with light instead of electrons. Silicon photonics could significantly increase the power and speed of machines such as supercomputers, data centers and the specialized computers that direct autonomous cars and drones with collision detection.

Artificial Intelligence - Continual advances in the use and deployment of artificial intelligence (AI). AI is defined as the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. Ostensibly it can include the ability to make decisions with information collected and adapt to the situation.

The combined effect of these three elements will significantly advance not only each nodes capability, but collectively the interaction of all the nodes with each other. Additionally, we are seeing the evolution of many common societal elements disappearing:

- It is predicted that 30% of Shopping malls will soon be gone within 5 years.
- Grocery stores – increasing possibly to autonomous delivery vehicles
- Jobs such as sales clerks which once required manual labor could soon become a job done by drones/robots. Another societal change would be the mailing system. The mailing system has already begun to change with non-packaged mail turning to electronic delivery.
- The farming community will change – automated system, more computation assessment of when to plant, fertilize, water, harvest, etc.

I have noted the potential efficiency that could come from rise of the use of smart technology. I have discovered, despite some discussion surrounding these smart nodes, very few have actually begun to address the most important question, how to execute and develop these smart nodes? Not only should one think about how these smart nodes will be built, but how and where will this technology will be tested?

An article from [https://www.technologyreview.com/s/610249/a-smarter-smart-city/](https://www.technologyreview.com/s/610249/a-smarter-smart-city/) does mention a small scale test of a “smart grid” in a small town, however, many citizens are leery about the smart grid’s ability to collect and share information on the citizens. Given the climate around cyber security and the recent scrutiny of Facebook’s use of its users’ private information, not only will the challenge of creating a smart city be coordinating all the nodes together, but also how to gain support of the citizens. Ultimately, the smart city is meant to benefit society, hence the citizens.
The Impact on Architecture:

Despite the buzz around the idea of smart cities, what has been overlooked in the discussion is the inevitable impact these nodes will have on the future of architecture. In the article http://labs.sogeti.com/smart-city-iot-design-architecture/, the idea of a smart city enhancing the experience of the citizens is touched upon. It has been predicted there will be 30 megacities having a population of 10 million around the world. Knowing cities consume about 75% of the world’s energy and produce 80% of greenhouse emissions, incorporating “smart” technology within the city could lead to less congestion of traffic, better efficiency, including better responsive to disasters and management of crisis. Previously mentioned was the prediction of 30% fewer malls within the next 5 years. With such massive space soon to be deserted, architecture could make use of this space. There are numerous possibilities, one being to repurpose the space as charging stations for vehicles.

Residential: With the growth of car-sharing services, it becomes less likely that homeowners will need garages, driveways or the associated costs of maintaining, insuring and fueling a vehicle. Communities will be planned to accommodate piloted or autonomous vehicles to pick and drop off people and goods and services. Individual driveways may become obsolete, for example, the US, people drive an average of 10,000 miles, or 200 hours per year. A car sharing service typically charge $8/hour, for entry level vehicles, and includes gas and insurance. If one does all their travels using car sharing services it would cost about $1,600 per year. To buy a $25,000 car over 5 years would cost $450 a month or $5,400 a year. Maintenance averages $900 a year. Insurance is typically about $1000 per year. Gas would be about $1000 a year at 30 miles per gallon. Total cost of ownership would be $8,300 a year, not including the cost of your garage over the life of your mortgage. So the cost of car ownership is over 5 times the cost of using car sharing services. Car sharing also allows you to rent the specific type of vehicle you may need each day – trucks, vans, sport cars, etc. So as car sharing services proliferate, society evolves to that type of mobility, changing what is needed residentially. One might consider that new residential facilities could include Autonomous Vehicles as part of the service/benefits provided by the building, and the use of them could be included in their monthly fee.

Another example of residential architecture changing, could be how recycling is done. To create a more efficient garbage/recycling rather than having a garbage truck visit each house, there could be a community garbage/recycling space for all cans to be located. Houses may have porticos for people and grocery/shopping bag drop off and pick up for car-sharing or the use of drones.

Automated snow plows, could clear roads in the late or early mornings allowing for traffic to continue as usual. While many states website that these possible uses of smart technology, at the moment, there appear to be no economically feasible means for these ideas to be implemented.

Institutional/Commercial/Industrial:

With the increase in car sharing and the future of autonomous vehicles, commercial buildings such as grocery stores or an institutional building like a hospital or school need to adapt for a more efficiency. One such design could be a change in parking lots. The creation of a common drop off and pick up zones, remote parking, more entrances, waiting areas, and more delivery bays should be considered. With these possible additions and redesigns, congestion of traffic could decrease significantly.
While public entities have historically been slow to implement technology, it will be critical for them to understand these technological advances (autonomous vehicles and “smart” nodes) and identify what their needs are and learn about the benefits of the smart cities. All these new uses of technology allow for a new field to be opened, however we must all focus on the fields that will be affected. Urban planning and design needs to adapt. Efforts need to be made in the designs for residential, industrial and commercial architecture to accommodate the changing urban landscape.

**Summary**

As can be seen, the question is not about whether or not these smart nodes will become prevalent within society. The question at hand is how fast is the growth of these nodes and how will these nodes be integrated into society? While Ford recently announced their intentions with the smart vehicle and technology to change the automotive future and its role in the city, the success of smart cities and the intermingling/communication between all nodes needs to begin with the with the discussion that includes all nodes as well as making the smart city a more discussed topic within society and learning the public’s opinion. The fast growth society has seen in technology makes the advancement of these nodes within cities no longer just an idea for the distant future, but rather a very relevant and tremendous opportunity for the enhancement of present cities. However, the huge potential of these nodes also means there will be many obstacles surrounding every aspect of life to adequately consolidate these coming advancements into city life.

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