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The Internet of Things and the Importance of Modeling and Simulation

A look at why modeling and simulation capabilities are becoming an indispensable element of the Internet of Things toolbox.

By Dr. Margaret L. Loper and Alain Louchez, Georgia Institute of Technology, on August 3, 2015

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Among the plethora of projections concerning the Internet of Things (IoT), the pervasive thread in all of them is the sheer size of the expected associated market a few years hence. While the path to get there is still marred with uncertainty and uneasiness on how the whole process is going to unfold, there is common agreement that in a world where almost anything and everything is becoming potentially connectable the number of communications links and smart endpoints (sensors, actuators, etc.) as well as the induced complexity will be of a significantly different order of magnitude from those currently experienced.

But there are other considerations.

**Multifaceted Complexity**

By its very nature, IoT is entering a completely new territory (especially in consumer IoT) that is not fully mastered. At the same time IoT technologies aim at integrating (everyday) objects into the communications space, they also bring about a new set of challenges. For example, when it comes to wearables, new antennas and connectors in all kinds of form factor must be designed, with possible non-trivial ergonomic and health implications.

In addition, as it has been widely reported (http://www8.hp.com/us/en/hp-news/press-release.html?id=1744676#.VbJiUvlz9mM), IoT devices are also vulnerable to cyberattacks, sometimes with devastating consequences including but not limited to privacy breach. This risk needs to be rigorously researched and minimized.

As a result, the way IoT solutions are going to be designed, developed and deployed is bound to go through a radical transformation. Related methods and procedures will have to incorporate sound and thorough analysis, and technological and financial considerations will dictate that IoT innovations be modeled and simulated before going live.

As far as IBM is concerned, modeling and simulation (M&S) is already core to IoT’s “here and now”: “Modeling and simulation is a vital ingredient in creating the connected products at the heart of the Internet of Things. It can support early evaluation and optimization of designs and ongoing verification as changes occur—to make sure the right product is developed and delivered with the required speed and quality” (IBM website (http://www-03.ibm.com/software/products/en/category/SW861)).

The human mind is lazily comfortable with linearity, for instance when “things will change the same way they did in the past”. In this type of environment, forecasting is straightforward; modeling is simple and simulation does not provide useful insight.

However, in a universe fraught with “nonlinearities” of the kind shaped by a fast-growing pool of intelligent objects interacting with each other and submitted to a variety of contingent disturbances, extrapolations are no longer clear-cut. We are all experiencing this type of random output in traffic-related situations: how many times have we done things early “to beat the traffic”, well aware that during peak-hours leaving ten minutes later does not necessarily mean arriving at destination ten minutes later? Given the IoT complexity and scale, M&S is no longer a luxury, it is a necessity.

**IoT System Engineering Essential Requirement**

By many accounts, the Internet of Things is viewed as a “system of systems” (http://www.youtube.com/watch?v=h2br2_twhfw) or even “systems of systems” (http://dl.acm.org/citation.cfm?id=2642828). Like in any other system engineering endeavor, M&S is a critical foundational building block; it is used early in the lifecycle to determine the efficacy of a proposed product. It is an effective means of defining product requirements, and can be used to test and confirm the viability of meeting requirements, as well as to verify the performance of a product.

M&S is all the more needed since it takes place among the continuous and unstable interaction between enterprises and their environment. Enterprises are complex adaptive socio-technical systems. They consist of many independent agents, whose behavior can be described by social, psychological, and physical rules, rather than dictated by the dynamics of the entire system. The overall enterprise system adapts and learns often resulting in emergent patterns and behaviors. Given that no single agent is in control, complex enterprise system behaviors are often unpredictable and un-controllable.

It follows that creating a model, executing a simulation and performing experimental runs should become prerequisite steps in any IoT-related project or undertaking.

Use cases abound in the IoT ecosystem where M&S sheds useful light on the contemplated project. Healthcare, manufacturing and traffic management are a few examples among many where M&S is growingly playing a key role. M&S is critical to understand their complex issues, and support exploration of a wide range of decision possibilities in these systems.

Healthcare providers are faced with a fundamental transformation of the way they get paid for their services – pay for outcome is replacing fee for service. As financial incentives evolve, providers must concentrate on prevention and wellness to diminish risks of chronic diseases. M&S enables quick and cost-effective exploration of alternative healthcare delivery mechanisms (including use of IoT technologies) and their impact on key economic and health outcomes.

Researchers at the 8th International Conference on Digital Enterprise Technology in Stuttgart, Germany in March 2014, that was focused on disruptive innovation in manufacturing engineering towards the 4th industrial revolution (embodied in the arrival of the Internet of Things) outlined that “the simulation-based technologies constitute a focal point of digital manufacturing solutions, since they allow for the experimentation and validation of different product, process and manufacturing system configurations.” M&S is also helpful for global manufacturing, which is increasingly characterized by complex supply chains providing components and subsystems that are eventually combined to form final systems products for customers. One type of related risk is the possibility of counterfeit parts, designed either with malicious intent or intent to defraud, which can seriously impact product reliability, safety and lifecycle cost. Comprehensive upfront M&S provides a referential non-defect baseline.

Traffic congestion is a primary issue facing many of today’s urban and suburban areas. M&S can provide transportation facility managers with real-time and near-future arterial performance measures. For example, an approach using online data driven, microscopic traffic simulation utilizing point sensor data can provide real-time performance measures. Combining current and forecasted performance information will enable greater efficiency in the use and operation of existing transportation facility capacity.

Modeling and Simulation Are Central to the Return on Investment

While it makes technological sense to walk before running, i.e., to model and simulate before deploying, it must also make financial sense. Akin to insurance, M&S looks expensive before adversity strikes. IoT-focused businesses must understand that embracing M&S in project development and management is good business practice. A systematic process must be established.

It is noteworthy, perhaps as a guiding path for the private sector, that even at the Department of Defense, where M&S is a vital enabler of successful military operations, the need for well-structured, ROI-like metrics is paramount: “successful Department of Defense (DoD) Enterprise modeling and simulation (M&S) investment requires structure, planning..."

**Next steps**

M&S is a broad discipline with a wide range of technologies and methodologies. Academic and business resources in the field typically focus on a specific aspect with a different purpose (e.g., discrete event simulation in industrial systems vs. continuous simulation in electrical and computer engineering). There is a need for an all-encompassing approach, especially in the IoT arena.

M&S education and training might become even more critical as the effects of the IoT revolution, as recently underlined by Henry Kissinger in his latest book (“World Order”, Penguin Press, New York, 2014, p.343) “extend to every level of organization /.../ and governments, wary of ceding the new field to rivals, are propelled outward into a cyber realm with as yet few guidelines or restraints.”

We could very well imagine that a battery of additional M&S-based tests might be required to verify that the injection of IoT devices in cyberspace does not increase the national cyber vulnerability. Currently, Machine-to-Machine (M2M)/IoT devices already need to comply with a broad array of certification requirements coming from government agencies (e.g., in the US, FCC, to make sure that the device does not emit interfering signals), associations (e.g., PTCRB (PCS Type Certification Review Board) to ensure that the device does not harm the cellular network), carriers (e.g., radiation tests specific to each operator) and possibly other entities.

“Cyberspace has become strategically indispensable. At this writing, users, whether individuals, corporations or states, rely on their own judgment in conducting their activities,” Kissinger observes. "The Commander of U.S. Cyber Command has predicted that ‘the next war will be in cyberspace.’ It will not be possible to conceive of international order when the region through which states’ survival and progress are taking place remains without any international standards of conduct and is left to unilateral decision” (“World Order”, p. 346).

*This article expresses the views and opinions of the authors and does not necessarily represent the position of Georgia Tech, the University System of Georgia, or the State of Georgia.*

Dr. Margaret L. Loper is the Chief Scientist of the Information & Communications Laboratory (ICL) [http://www.gtri.gatech.edu/icl] at the Georgia Tech Research Institute. She is also the editor of the recently-published book on *Modeling and Simulation in the Systems Engineering Life Cycle* [http://www.amazon.com/Modeling-Simulation-Systems-Engineering-Cycle/dp/1447156331], Springer, 2015, which leverages the work of Georgia Tech research and teaching faculty to cover the breadth of M&S used in systems engineering. The book offers a helpful starting point for engineers and managers involved in the development of IoT systems.

Alain Louchez is the Managing Director of the Georgia Tech Center for the Development and Application of Internet of Things Technologies (CDAIT) [http://www.cdait.gatech.edu/].

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