Building Smart Communities for the Future: Proceedings of a Workshop–in Brief

DETAILS

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Proceedings of a Workshop

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IN BRIEF

BUILDING SMART COMMUNITIES FOR THE FUTURE

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Over half the world's population currently lives in urban areas, and the United Nations has projected that by 2050 that number will rise to 70 percent. Given the rapid urbanization trend happening around the globe, coupled with shifting demographics and disruptive technological change, many countries have started planning the development of smart cities and communities: urban centers that use intelligent, connected devices and automated systems that maximize the allocation of resources and the efficiency of services.

On June 21-22, 2016, the Government-University-Industry Research Roundtable (GUIRR) held a meeting to explore the role of connectedness and sustainability in developing smart communities, the challenges and opportunities associated with the roll-out of intelligent systems, and the partnerships among governments, universities, and industry that are integral to these advances.

The keynote address on June 21 was given by **Carlo Ratti**, the director of MIT's SENSEable City Lab, who explained some of the work underway at the lab. Ratti posited that in the 1990s people were fascinated by the digital world, and they thought that the physical world would become less important and that their lives would become increasingly virtual, to the point that in 1995 George Gilder, futurist, predicted the death of cities, which he called "leftover baggage from the industrial era." "No prediction could have been more wrong," said Ratti. "Cities have been thriving over the past few decades, and by 2030 there may be 5 billion people living in cities."

"Digital has not killed physical space," Ratti continued. "Instead, digital and physical are re-combining. The internet has entered physical space—becoming the Internet of Things (IoT)—and it is changing the way we interface with the space around us. Through networks and sensors we can understand the city in a different way and respond to that information. By 2020, the number of connected devices is expected to grow to 50 billion; this will include not only phones and iPads but also sensors. Growth in these devices is producing a massive amount of data in our cities, and we can learn a great deal from big data in urban space."

Ratti provided an example: data reveals that for any two points in Manhattan, there are hundreds of thousands of car trips connecting them in the course of a year. Looking at shareability networks, his lab determined that ride-sharing could get everyone to their destination at the needed time, give or take a few seconds delay, while cutting the vehicle fleet by 40 percent. Although the paper describing the full results of the analysis just came out recently, the first results came out a few years ago and came to the attention of Uber, which then started its Uber Pool ride-sharing service. Every shared car suggests removing a car from the streets, which implies less congestion and fewer emissions.

Ratti's lab is also exploring how to better match buildings' energy use with how and when people use buildings, since currently those are not synchronized. His team monitors occupancy and energy use in MIT buildings and is exploring whether it is possible to put energy only in places where there are people. The goal is to design a building where heating would follow a person as they move through a space, shutting down in unoccupied spaces.

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As a final example of SENSEable City Lab's work, Ratti explained the lab's experiments with tagging and tracking trash. They worked with Qualcomm to design a little tag that is placed on an object and sends a signal, allowing those monitoring it to track where it goes. They recruited volunteers to tag 3,000 pieces of trash in Seattle, and then monitored where the pieces of trash went. Much of it went to landfills outside Seattle, but study organizers were surprised by how far outside of Seattle some of the trash traveled—one piece went to Chicago, and then to California. Some pieces were still on the move after one or two months. Ratti suggested this kind of data could be used to optimize how trash is disposed of, in order to design a more efficient system and save energy.

SMART CITIES INITIATIVE IN THE STRATEGY OF AMERICAN INNOVATION

The first presentation on June 22 was given by **Dan Correa** from the White House Office of Science and Technology Policy, where he leads the White House Smart Cities Initiative. Correa offered an overview of the latest update of the White House's Strategy for Innovation, which includes more than a dozen strategic initiatives, from precision medicine to clean energy to high-performance computing. The Smart Cities Initiative emphasizes a clear opportunity: technological advancements and the diminishing costs of infrastructure have unlocked the ability to analyze large data sets efficiently, while enabling the prevalence of low-cost networks such as the Internet of Things.

"The list of challenges preventing the tech-enabled future is just as clear," said Correa. "For example, city leaders need to be convinced that these investments are worth making, and it is difficult for them to be the first ones to do it. And pursuing smart cities is complicated, because a lot of stakeholders need to participate in order to deploy new technologies in cities. Cities also have limited capacity for long-term planning."

The White House launched the Smart Cities Initiative to help cities overcome some of these challenges. The initiative includes three parts: (1) R&D investment—the White House announced $160 million in investments but by now has invested over $200 million; (2) test beds, meaning multi-sector collaborations to try new technologies in cities; and (3) a focus on multi-sector partnerships that involve universities, entrepreneurs, companies, and government.

"NSF is making significant investments in this area," said Correa. In the fall of 2015 NSF announced $35 million in awards to invest in the research infrastructure underpinning smart cities. The U.S. Department of Transportation's Smart City Challenge also put out $40 million and asked cities to craft their own vision for their urban transportation future, such as smart transportation systems and self-driving vehicles. Correa also offered examples of initiatives outside the federal government, including a new nationwide nonprofit called Envision America that is going to choose 10 cities to try out new smart cities approaches.

"These examples illustrate the public-private collaborative model that has worked so well," said Correa. "Even though the administration will be out of office next January, it will continue to grow the Smart Cities Initiative. We're thinking hard about how to work collaboratively with outside partners, communities, and agencies to institutionalize these efforts and find the right partners to carry them forward," he said.

CITY-UNIVERSITY PARTNERSHIPS AND THE METROLAB NETWORK

The next panel was a Q&A with participants about city-university partnerships and the MetroLab Network, moderated by the network's interim director, **Ben Levine**, who gave an overview of the initiative. "The idea of a city-university partnership makes sense," he said. "It's a marriage that is attractive to both cities and universities. Cities have challenges they are trying to solve, such as inequality and problems with the built environment. Universities are tools that can help solve those challenges, functioning almost as R&D departments for city government. In return, cities function as test beds, letting universities learn more about how technologies work."

"After creating those city-university partnerships around the country, the next logical step is to connect them, because cities often face similar challenges," said Levine. The MetroLab Network is intended to connect these city-university partnerships. As of June 2016 the network had 35 cities and 45 universities organized in 30 regional partnerships—often one city with one university, but sometimes multiple cities or multiple universities. Currently, there are 100 research, development, and deployment projects going on in these partnerships across the country.

The network focuses on three activities: (1) fostering strong partnerships where the university is working with the city on a regular basis, across disciplines and across city agencies; (2) identifying opportunities to scale approaches and transfer them from one city to another; and (3) creating a platform upon which cities and universities can organize and collaborate to solve grand challenges facing cities.

Levine then facilitated a discussion with panelists who all participate in the MetroLab Network: **Michael Mattmiller** of the City of Seattle, **Tom Schenk** of the City of Chicago, **Sandra Brown** of the University of California, San Diego, and **Jonathan Fink** of Portland State University.

Levine asked the panelists to describe the MetroLab projects they have underway. Fink explained that Portland's projects focus on a couple of transit corridors. One corridor, which includes one of the poorest and most diverse parts of Portland, will have a bus rapid transit line within 4 years that runs into downtown, which is being implemented to improve these communities' access to technology and economic opportunities. Sensors will be deployed before, during, and after construction to assess the new transit corridor's impact.

"UC San Diego has three new projects underway," explained Brown. "The first is developing a bio-regional approach to water and agriculture. A second project focuses on the Internet of Things—mainly transportation, with sensors that indicate real-time changes that need to be made. A third project is developing models that relate university involvement, industry partners, and governments collectively in solving problems."

Noting that Chicago has a number of projects, Schenk focused on explaining the Array of Things project. Argonne National Lab and the Urban Center for Computation and Data at the University of Chicago worked with the city to develop the idea. They deployed 300 nodes, each with about two dozen sensors that measure things like temperature, humidity, and pollution, as well as cameras that count people and cars so that they can assess population density. "This information can help the city better deliver services," Schenk explained. "For example, they can identify which streets need frequent snow plowing and others where heavy traffic keeps the roads clear."

Mattmiller said that one of Seattle's projects is about learning from what other cities are doing. Seattle will be in the second round of cities to implement the Array of Things and will receive its first 10 nodes in September 2016—one of the main goals of which will be to better measure rainfall in Seattle. A second project will look at how different environmental conditions, such as moisture and temperature, affect electrical transmission line conditions, with the goal of reducing energy loss. The third project is about privacy. Matmiller noted, "Seattle is very focused on individual liberty, and to succeed, any IoT project must build trust in the community. So the project is examining how municipalities collect data and make it available to the public, as well as the kinds of protection and engagement strategies they should put in place."

Levine asked Fink and Brown about incentives for research universities to participate and how universities manage these types of projects. Brown replied that UC San Diego's strategic plan is "student-centered, research-focused, and community oriented," and that framework has allowed them to consider opportunities in their community. Fink said that Portland State is an urban-serving public university whose motto is "Let knowledge serve the city." Fink also stated, "Portland State can't compete against UC San Diego on the basis of the quality of its chemistry or biology department, but when it leverages its local partnerships—with the city of Portland, with the local medical school, or with Intel—it can compete. Faculty members know that they are more likely to get NSF grants when they work with the city on one of its projects than if they apply for them in isolation."

Levine then asked how city staffers manage the longer timelines of research projects, given that they are also dealing with fire drills and short-term projects. Schenk explained that partnerships with universities allow city staffers to focus on their short-term projects, because the long-term projects have a long-term university partner to help anchor them. "A good research project has people thinking about it day in and day out, and that's essential to achieve some of the projects the city wants to achieve, but that does not work well for city staffers who have a dozen items that need to be turned around on a short-term cycle," he said. "So the partnership allows ideas like the Array of Things to thrive and be successful."

"One secret ingredient from the university side is involving students, who are on the same short-term timeframe as cities—they want to get things done," said Brown. "We have a responsibility as a university to be responsive even

to some of the city's short-term needs, so we need the right kinds of academic incentives to make that viable for our faculty." UC San Diego is trying to change the way it does academic reviews to consider things like patents and intellectual leadership in setting up large databases.

The panel members also discussed their experiences pursuing the DOT's Smart Cities Challenge. "The Challenge advanced Portland's progress on transportation issues by five years," said Fink. "It has been transformative, and we'd like to see more of these challenge grants come along." Mattmiller also commented that the Challenge was an impetus for people to work faster and to work together on some great ideas that otherwise would have been "relegated to a B list."

INDUSTRY AND THE SMART COMMUNITY

The next session focused on Industry and the Smart Community, moderated by **Erik Antonsson**, GUIRR University-Industry Partner and Corporate Director of Technology at Northrop Grumman Aerospace Systems, who opened the discussion by pointing out that employers are natural partners with cities. "Employees depend on city infrastructure, and companies often choose to site a location based on the quality of that infrastructure. This partnership has not been focused on and utilized as it should be," he said.

Cate Richards of IBM explained how her team approaches smarter cities work—conducting business value assessments up front and identifying the goal that the technology will be expected to accomplish. "A city is a system of systems, and we drill down to look at how all of the parts interact with one another," she said. "For example, fewer road closures for construction means less congestion, and easing traffic congestion improves emergency response times, which makes a safer community. That's how we start to assess the true value of the investment we're considering and decide whether we are going to proceed."

"We have found that the best value and return on investment come from addressing the gaps between agencies and facilitating communication between them," said Richards. "For example, cities want to avoid frustrating citizens by digging up the same stretch of road multiple times—first to access gas, then sewer, then cable lines—which happens because multiple agencies and multiple companies are not coordinating and planning with one another."

Miami-Dade was one of the first places where IBM pursued smarter cities projects. The county needed to find $1 million in savings in order to save an at-risk youth program in the parks. IBM found the money by optimizing water use in county parks. The company installed an intelligent water hub that used leak detection and geospatial mapping to take about $750,000 in overwatering out of the park system; this in turn saved about $250,000 in energy, because water is heavy to lift. "It was a success that Miami-Dade—which now has many smarter cities projects—keeps building on," said Richards.

The next presentation was offered by **Sameer Sharma**, who directs Intel's new market development for the Internet of Things. "Intel is keen to participate in the smart city revolution," he explained, "and in doing so it wants to stitch together everything it has as an asset: its chips, security software, and device management solutions for the IoT." In addition, Intel Capital invests $300 million to $500 million per year, making it the single biggest IoT venture capital firm in the world.

Sharma identified three areas that companies and partners need to work together on to bring IoT devices on board and to communicate with each other. The first is smart cities infrastructure—when Sharma travels and asks cities what is important to them, they say protecting critical city infrastructure (roads, bridges, data centers), the ability to respond quickly to emergencies, and resilience of city services. The second is that 5G—an umbrella term for many digital infrastructure technologies that will need to be developed between now and 2020—is being designed to incorporate 7 trillion things worldwide, which amounts to about 1,000 devices for every person on the planet (see Figure 1). Sharma suggested we need to design the network to accommodate that level of capacity, meaning "wireless capacity will need to be increased 1,000 times over what we have today with 90 percent less energy." The third area Sharma identified was standards—Sharma stated, "It is not feasible to have a single IoT standards body; instead, there will be different organizations with different focus areas."

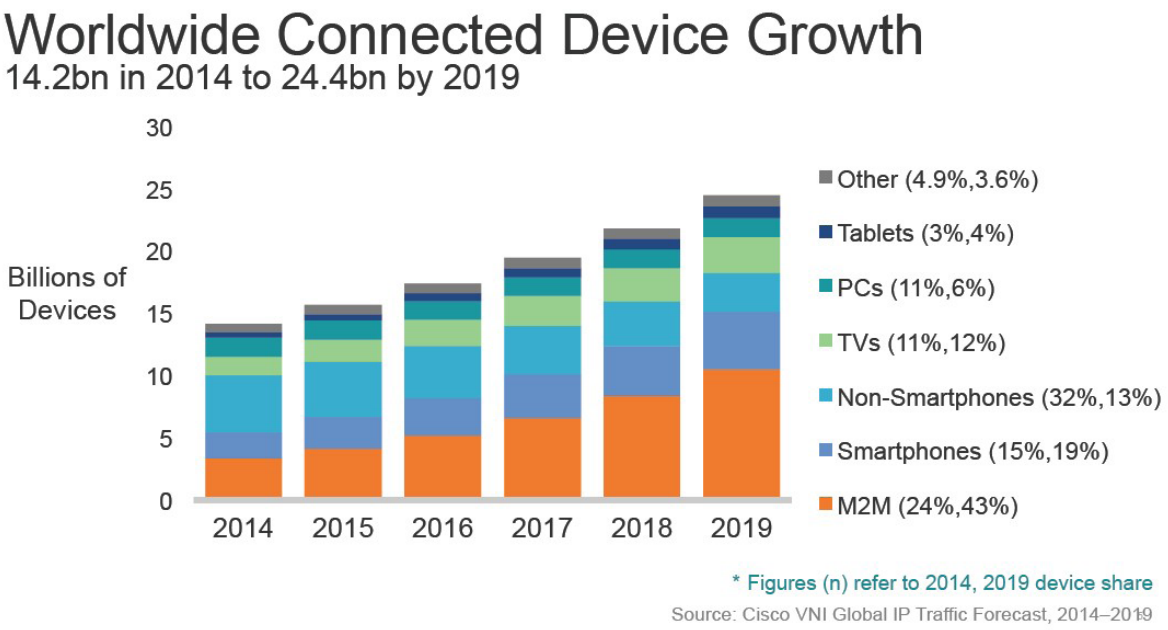

Figure 1 Worldwide Connected Device Growth; presentation by John Garrity to GUIRR, June 22, 2016. Source: John Garrity.

The next presentation was offered by **David Zipper** of 1776, a global startup hub and seed fund that was founded three years ago to focus on catalyzing innovation worldwide in life-critical sectors such as education, health, smart cities, food, and energy. Headquartered in Washington, DC, 1776 has campuses in San Francisco and Virginia and is building offices in New York and Dubai. It has about 450 startup members and touches about 3,500 startups per year, so it is among the biggest startup hubs in the world.

"There is tremendous opportunity for the growth of smart city technologies in life-critical sectors," said Zipper. "These are multi-trillion dollar sectors, and they are not performing the way they should. And technology—such as the rise of mobile and the cloud—has lowered the bar to entry for start-ups who want to do something innovative in these sectors." Zipper noted that there are still many challenges in these sectors: they are risk averse, (in some cases rightly so, when lives are at stake); there is regulatory complexity that can shut down startups before they launch; and there are scaling challenges. "1776's mission is to help entrepreneurs overcome these challenges."

The company works to bring together a variety of resources to support startups, such as a curriculum of classes on topics ranging from "How to Pitch a City" to "How to do Customer Segmentation." In addition, 1776 has a seed fund to invest in the early-stage startups they work with, co-working spaces, a media platform and events area, and a world-wide network of over 1,000 mentors who give feedback to startups to help them understand challenges they're facing and gaps in their knowledge and experience. Among the mentors in the smart cities space are contacts at UBER, the Seattle Department of Transportation, Xerox, Global Automakers, and the Boston Mayor's office.

Several hundred smart city and transportation startups in areas ranging from urban mobility to homelessness to urban gardening are working with 1776. "It is part of my job to curate these and to know who is doing well and who is not ready to scale and who is selling vaporware," said Zipper. As part of the Smart Cities Challenge, 1776 organized a workshop that brought together 400 people—including representatives from 40 cities—to learn about how to set up effective partnerships between cities and startups.

GLOBAL CITY TEAMS CHALLENGE

The next presentation was offered by **Sokwoo Rhee** of the National Institute of Standards and Technology, who leads the Global City Teams Challenge. The challenge aims to create a replicable and scalable model for incubation and deployment of the Internet of Things and cyber-physical systems, with the goal of improving the quality of life in smart cities around the world.

"One way of defining Internet of Things is as a layered system," Rhee said. "On the bottom layer is hardware, such as chips, devices, even cars and planes—things you can touch. On top of that there is a communications layer—Wifi, Zigbee, cellular networks—that connects. Many people think of the IoT as these bottom two layers, but there are two layers on top of them that are probably more important. After data is collected through the bottom layers, data analytics are used to extract useful information from the data. On top of that, there is a service layer, where decisions are made and actions are taken; this is where real value is created, and humans may be needed for this layer. When you apply this IoT to the public sector, it becomes a smart city."

"Many smart city projects are fascinating, but there are issues," said Rhee. "A major issue is that many projects are one-off projects that are tailored to the needs of a particular city, which means that there are no economies of scale. Lack of measurability is a problem as well."

"The Global City Teams Challenge attempts to create an incubation and deployment model of replicable, scalable, and sustainable solutions," said Rhee. "Instead of each city working with a company one-by-one, we want multiple cities to jointly address issues and coalesce around the topics and come up with joint solutions. We bring in municipal governments, companies, academic institutions, and nonprofits and start the process of team-forming; eventually we want deployment and for them to report the results. Even before starting deployment, we want the teams and project managers to think about the operational and business sustainability of the project." About 160 cities have taken part. The Challenge has agency partners, industry partners, and country partners, including the central governments of the Netherlands, Italy, South Korea, and Japan.

ROLE OF SUSTAINABILITY AND DEVELOPMENT IN GLOBAL SMART CITIES

The final smart cities panel was moderated by **Andrew Reynolds** of Science, Engineering, and Technology for Development, who offered an overview of the United Nations Sustainable Development Goals (SDGs) and related efforts in 2015 to plan future sustainable development. A common theme in these efforts was the recognition that science, engineering, and technology, including information and communication technologies, are seminal assets in addressing the SDGs.

John Garrity of Cisco Systems spoke about some of the work Cisco is doing around the IoT, particularly in service delivery in developing communities. Cisco partnered with the UN International Telecommunications Union to examine how to apply the IoT to help drive sustainable development, focusing on the 17 SDGs (see Figure 2).

"A lot of work exploring the IoT has focused on advanced economies and industrialized sectors," said Garrity, "But there is a way for the IoT to make a difference in low and middle income countries and outside urban areas by improving service delivery in peri-urban and rural areas."

For example, currently rural farmers in India have to go to different parts of their land and turn on micro-irrigation pumps, but only when they know that there is water flowing through the irrigation canal. Cisco has explored how to pair sensors with basic feature phones; the sensors detect whether there is water in the irrigation canal and send a text notifying the farmer, who can then turn on the micro-irrigation pump using the phone's keypad.

"Much of IoT development so far has been in person-to-machine or machine-to-person communications, or both. But what's driving growth in terms of IP-connected devices is machine-to-machine connections," said Garrity. "While the digital divide in internet connectivity may be closing as more people in sub-Saharan Africa and in India and China have access to mobile phones, there is a large digital divide in terms of machine-to-machine devices per capita—a gap that is likely to widen."

Figure 2 Sustainable Development Goals; presentation by John Garrity to GUIRR, June 22, 2016.
Source: John Garrity

Cisco released a report that looked at 20 case studies of how the IoT is being used to improve service delivery and support community development. For example, work is being done to use thermometer sensors to monitor the temperature in the coolers and refrigerators where vaccines are transported and stored, with the goal of reducing vaccine spoilage. Sensors are also being used in networks to detect fires in slum areas, which are fast moving and often difficult to locate, and to notify neighbors and emergency responders. "Some of the remaining challenges to adoption of these methods are ensuring the reliability of devices, improving the ability to scale, issues of power outages when using sensors in remote areas, standards and interoperability, and ensuring trust and confidence in systems," said Garrity.

Andrew Turner from Esri R&D Center explained how the center uses geography and geospatial mapping to help cities around the globe become sustainable and resilient. Turner and his colleagues are applying a new pattern called geodesign. "Usually maps and data are 'read only,'" said Turner. "But Esri wants to make them bi-directional so that users can not only look at a map, but also ask questions of the map and of the environment around them using sensors and data to form complex questions, get meaningful answers, and observe changes over time."

One way Esri has been monitoring and visualizing this is through a project called Urban Observatory. The Urban Observatory lets people compare 20 different themes across 30 different cities, at common scales. Users can compare urban footprint, population density, and sprawl; as users zoom in on one city, the maps of other cities adjust to the same scale. So, for example, a user can see traffic congestion and how policies affect it across cities. "We're trying to take the technology that's been used by governments for decades and turn it around and provide it as a public digital infrastructure to help the civic population participate at a level equal to the government," said Turner. "We apply three principles when we bring this to the web: (1) make the data easy to explore and discover; (2) build new technologies; and (3) share them with others."

"We start by looking at cities and understanding what they want to accomplish: What are the executive orders and longstanding decadal issues cities are trying to address? We then contextualize our analytics to address those core issues. Police departments, environmental agencies, and educational institutions are already working together on these issues, and we help them collaborate better together. But the ultimate goal is to invert that data and information technology to enable the engagement of constituents on the ground—whether they're citizens, universities, schools, businesses or other organizations."

Turner and his colleagues are now applying this approach to Secondary Cities, a project run through the U.S. State Department in which Esri partners with universities in developing cities to advise them on how to apply these techniques and technologies to solve their issues.

The final presentation was offered by **Reginald Vachon** of the World Federation of Engineering Organizations (WFEO). He gave an overview of the WFEO's standing technical committees, which cover a wide range of topics: energy, education, anti-corruption, women in engineering, innovative technology, and disaster risk management, information and communications, engineering capacity building, engineering and the environment, and young

engineers and future leaders. Each committee is chaired by a different country, and there are about 10 to 20 people on each committee. WFEO has divided up the Sustainable Development Goals and the National Academy of Engineering's Engineering Grand Challenges among the committees so that all are covered.

To address these goals, WFEO has an approach that starts with defining an objective, followed by developing requirements, and then considering many alternatives. "Because we have constraints and criteria, we then conduct a trade-off analysis, which leads to a result. If necessary, we iterate and go through the process again."

"The most important thing we must do is address social sustainability and think of communities," said Vachon, reiterating John Garrity's prior call for the importance of having rural, peri-urban, and urban areas working together. "The biggest deterrent to people working together on smart communities is limited broadband capability."

DISCLAIMER: This Proceedings of a Workshop—in Brief was prepared by **Sara Frueh** as a factual record of what occurred at the meeting. The statements made are those of the author or individual meeting participants and do not necessarily represent the views of all meeting participants, the planning committee, or the National Academies of Sciences, Engineering, and Medicine.

REVIEWERS: To ensure that it meets institutional standards for quality and objectivity, this Proceedings of a Workshop—in Brief was reviewed in draft form by **Carla Bailo**, Ohio State University and **Jeff Welser**, IBM Almaden Research Center. The review comments and draft manuscript remain confidential to protect the integrity of the process.

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