A Preliminary Update from the Internet of Things Federal Working Group

July 2023

Introduction

The Internet of Things Federal Working Group (IoTFWG) is a collaboration of Federal stakeholders providing recommendations and a Report to Congress regarding adoption and actions that the US Government can take to promote and enable the Internet of Things (IoT). IoTFWG is gathering and evaluating information from the community and other sources. This publication provides an update to readers about the progress of the working group.

Recognizing the potential and economic and societal benefits of the IoT, the U.S. Congress in the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (NDAA) established both the IoTFWG and an IoT Advisory Board (IoTAB) to advise the IoT FWG. The NDAA requires a report that documents how the US economy, US citizens and US private sector can benefit from IoT technology, identify programs or policies to help promote IoT development and record factors that are inhibiting or may inhibit IoT adoption. IoT considerations were also the focus of the "Developing Innovation and Growing the Internet of Things Act" or the "DIGIT Act" (S.1611 — 116th Congress (2019-2020). The DIGIT Act recognized that IoT "has the potential to generate trillions of dollars in new economic activity around the world in the transportation, energy, agriculture, manufacturing, and healthcare sectors and in other sectors that are critical to the growth of the gross domestic product of the United States." The Act recommends "the appropriate prioritization of a national strategy with respect to the Internet of Things". This builds on the unanimous passage of Senate Resolution 110, 114th Congress, calling for a national strategy for development of the Internet of Things.

As the IoTFWG continues to prepare its June 2024 Report to Congress, this update provides an early view into the proposed strategic pillars of the planned roadmap identified based on inputs received from the IoTAB and other stakeholders.

Section 9204 (b)(4) directs the working group to consult with diverse nongovernmental stakeholders with expertise relating to the Internet of Things and this paper offers an opportunity for feedback from a broad set of interested parties. IoT affects every area of the country and all entities, from individuals to public- and private-sector organizations.

IoT affects every aspect of our lives, from rural farms to city avenues, from homes to offices to factories, so the IoTFWG welcomes all input.

Feedback from the community is welcomed, particularly in areas highlighted in green boxes like this one. Comments may be directed to: iotfwg@nist.gov

The Strategic Environment

To gain the benefits of IoT, Congress and the many members of the Federal Government recognize the need for a comprehensive roadmap or strategy. IoT will create economic opportunities for small and large businesses as they develop services and products, improve the efficiency of operations and logistics, cut costs, and improve worker and public safety. These cost savings and efficiencies will enhance consumers' lives and bring innovations – some of these improvements will represent conveniences while others will be life-changing, such as those in healthcare and safety technologies. IoT plays a vital role in emerging artificial intelligence (AI) and advanced computing capabilities that are expanding daily. Using trustworthy implementation, it can bring open architecture and interoperability, helping aggregate and fuse real-time data into cooperative and actionable information, including machine-to-machine automation.

The IoTFWG Report to Congress will describe broad benefits in several areas, including:

- ✓ Sustainability
- ✓ Cost Reductions
- ✓ Workforce productivity
- ✓ Societal Impacts
- ✓ Public Safety
- ✓ Health
- ✓ Equitability

The IoTFWG, drawing on recommendations from the Advisory Board and other stakeholder input, such as feedback on this publication, will highlight benefits and opportunities in specific sectors, including:

- **Logistics and Supply Chain**: IoT can be used to improve the efficiency and transparency of supply chains by tracking the movement of goods and materials to ensure appropriate levels of availability and facilitate the relocation of supply to where it's needed. Augmented logistics will help track materials throughout production, warehousing, and distribution.
- **Healthcare**: Extensive improvements are made through the use of connected medical devices as new devices provide better patient monitoring, medication delivery, and even embedded and implanted sensors. The advancement of this technology increases accessibility to all patients by monitoring patients remotely and providing them with personalized care.
- **Agriculture**: IoT can be used to improve the efficiency and sustainability of agriculture by monitoring crops, livestock, and soil. Precision IoT helps reduce the use of fertilizers and other chemicals, minimize water consumption, and improve yields and crop production. Many farming activities are labor-intensive and are supported by increased automation.
- **Energy**: The IoT supports improved, efficient, and reliable energy systems through automated monitors and controls, enabling resilient generation and distribution through smart grid infrastructure. Automated home and building management systems help reduce energy use, providing further cost savings and environmental benefits.
- **Transportation**: Safe and reliable transportation has never been more vital. IoT improves the safety and efficiency of cars, railways, trucks, and many other modes of transport. Today's automobiles are rolling internetworks with hundreds of sensors and controllers rapidly exchanging data through secure, low latency communications, including emerging crash prevention technologies and numerous safety and reliability improvements. Similar technologies are pervasive throughout the transportation industry, supported by an intelligent infrastructure that enables and connects the various components.
- **Public safety**: IoT monitoring and reporting improve the safety of our citizens and communities. The health and safety of citizens everywhere are increasingly protected via cameras, sensors, and communications tools that help to detect crime, monitor weather conditions, inspect and observe infrastructure, and other helpful actions, the health and safety of citizens everywhere are protected. IoT

directly protects first responders by monitoring air and safety conditions, reporting locations in hazardous environments, transporting them to incident locations safely and efficiently, and improving communications among personnel.

- **Manufacturing**: Improving the efficiency and productivity of manufacturing by monitoring and controlling production equipment while ensuring high product quality is another benefit of IoT. Tracking parts and monitoring the state of partially finished goods can improve efficiency and reduce downtime.

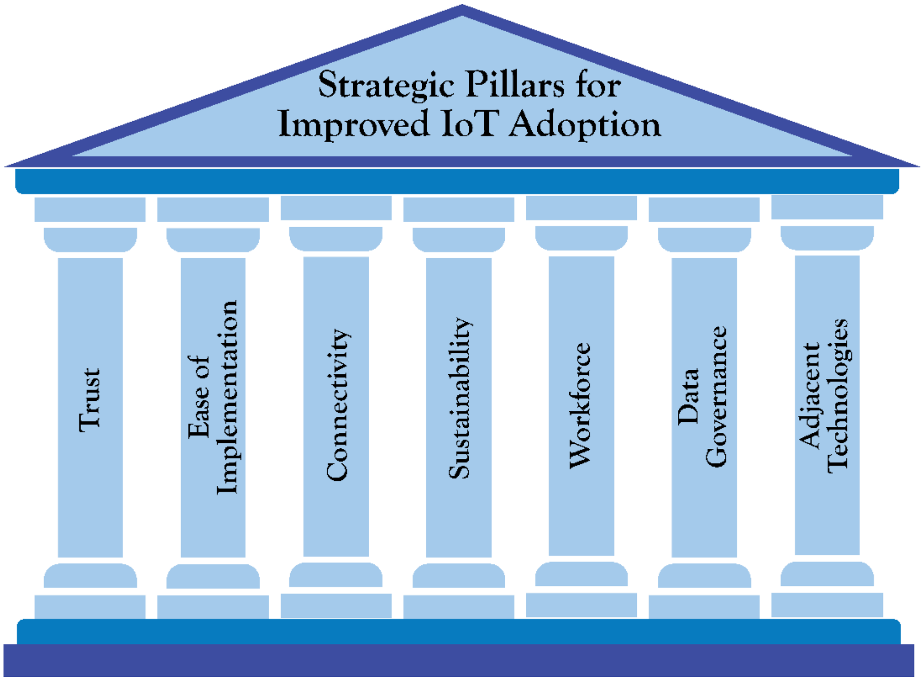
Notably, IoT has the potential to significantly improve the equitability of access to these and other benefits. The information and abilities that IoT and associated technologies provide are vital to the prosperity of individuals and businesses. A 2022 report from the World Economic Forum reported that effective digital transformation "presents a generational opportunity to close the [digital] divide and help level the playing field. This transformation requires a close partnership between schools, governments, non-profits, and private organizations to create a technology ecosystem with equitable access to opportunities for underserved communities worldwide."[1] IoT is a key part of that transformation, and the IoTFWG continues to seek ways to improve that equitability and ensure access to the benefits described above.

Join the conversation: This is a starting list of the benefits enabled by expanded use of the Internet of Things. Are there additional benefits (or specific instances of use cases showing benefits) that should be included?

[1] https://www.weforum.org/agenda/2022/01/equitable-digital-transformation-business-leaders-davos-agenda-2022-digitization

Strategic Pillars for Improved IoT Adoption

The IoTFWG has identified a distinct set of critical focus areas for a roadmap that will help the nation achieve its goal of adopting IoT and receiving the benefits described above. These strategic pillars represent key areas necessary to enable and advance IoT adoption.



Based on feedback to this publication, as well as recommendations from the IoTAB, the Final Report will identify government actions that can support and advance these pillars, and reduce barriers, where possible.

Pillar 1: Trust

Successful adoption of IoT technology depends heavily on gaining the trust and confidence of the organizations, agencies, consumers, and others that will implement and expand its use. IoT provides powerful benefits, as described above, but reaping those benefits requires placing sensors and devices in physical locations that can be highly sensitive and intrusive. While IoT promises exciting innovation and advancement opportunities, trust in that technology (and in the protection of associated data) by industrial adopters and other stakeholders is a key prerequisite. Consumer trust considerations certainly influence IoT adoption, such as for smart home technology and security systems. This includes all the dimensions of trust including the safety and reliability of the IoT products as well as their security and privacy.

Still, the IoTFWG's Report to Congress must also focus on vital aspects of commercial and municipal adoption. For businesses to entrust their livelihoods and corporate assets to such technologies, adopters must have complete confidence in the data protection mechanisms that undergird the sensors, applications, storage, analytics, and related components. Mechanisms for ensuring reliability and confidence in data protection will be vital to attaining the promises of IoT.

There has rarely been a conversation about IoT that did not turn to the subject of cybersecurity. Cybersecurity is far from the only IoT-related trust factor, but it is vital to gaining and retaining the confidence of all who use IoT. The value of the Internet of Things lies in the ability to convert manual procedures to automated processes that generate significant amounts of raw information.

This data can expose nearly all of an organization's internal mechanisms, from manufacturing to operations to distribution. An entity's secrets can be exposed to these devices in exchange for efficiencies. Therefore, there must be specific mechanisms for users to ensure that IoT devices and supporting infrastructure are suitable for the intended purposes and that suitability can be asserted through a reliable method. Risk management needs will vary depending on the mission and purpose of the technology. Security of IoT and associated technology is an essential element of national security since, without technology security, the nation cannot enjoy economic security.

Ensuring an acceptable level of risk extends to assurance of a trustworthy development and distribution supply chain of an IoT device or service. There must be mechanisms that increase confidence in the pedigree of IoT technology and processes, especially where IoT affects critical areas such as health and safety. This includes, for example, having sufficient information about devices being marketed and distributed and identifying counterfeit devices that often suffer from quality and security deficiencies so that users can make appropriate and informed decisions. The IoTFWG recognizes that supply chain security is related to but different from a sustainable and reliable supply chain. Both are necessary elements.

For the nation to realize the extensive economic benefits in the transportation, energy, agriculture, manufacturing, and healthcare sectors and in other sectors that are critical to the growth and prosperity of the United States, trust in reliable operation and data protection must be assured.

Pillar 2: Ease of Implementation

While today's IoT represents amazing innovation and technical advancement, widespread adoption and implementation will require significant improvement in the cost and availability of IoT technology. Businesses nationwide will benefit from new services and products and improved efficiency of operations and logistics. Gaining these benefits requires significantly reducing the cost of devices and enhancing interoperability between technical components.

Interoperability is a critical success factor. Early generations of IoT have evolved quickly, with significant improvements and advancements through each product cycle. These advancements have resulted, in many cases, in the use of proprietary methods that may lock users into a particular vendor or class of products, limiting the ability of devices to operate with those of other manufacturers or technology types. These challenges are not new, and we have previously faced similar interoperability needs (e.g., Betamax videotapes, 8-track cassettes, and earlier generations of competing cellular telephone standards). No one wants to invest time and money into technology that will likely become obsolete. Proprietary technical mechanisms stifle competition and reduce availability, so the roadmap is expected to promote visionary planning and cooperation.

To ease implementation, there should be clear guidance, standards, and protocols for ensuring reliable and consistent communications where IoT components need to interoperate. Where existing and reliable data exchange mechanisms exist, these should be encouraged; where new models are needed, work should be quickly applied to improve and advance their availability. Reliability should include confidence that product and system types will likely remain relevant and operative.

Reducing the cost to develop, deploy and maintain inexpensive devices is vital to widespread IoT adoption. Producing less expensive devices depends upon advances in the size, power, and availability of microelectronic chips and related technology. For this reason, the roadmap will likely call for additional research into ways to continue improving IoT circuitry, including methods for reducing power consumption and heat generation. Research should include means to improve IoT technology's physical deployment, implementation, and maintenance. An interoperable IoT infrastructure that is easily managed will provide valuable benefits to the nation and its partners.

Pillar 3: Connectivity

By definition, IoT technology must be able to internetwork through some physical, ad hoc/mesh, or wireless capability. While communications technologies (e.g., satellite, cellular, broadband/Wi-Fi, and other traditional licensed communications technologies) have expanded in both geographic scope and capacity to accommodate higher data loads in recent years, the capabilities are not unlimited. This condition is exacerbated by the fact that, in many cases, the very places where some IoT sensors are needed, such as for remote security and environmental monitoring, are locations with limited connectivity. Scalability represents another IoT challenge: the communications infrastructure must simultaneously support hundreds of billions of digital conversations.

The roadmap will likely call for accelerated innovation to ensure improved communications by ensuring the availability of suitable and sufficient spectrum resources, the development of wide-area networking technologies, and enhancing interoperability. For example, the roadmap could include the exploration of 5G and satellite implementations to support connectivity to rural and underrepresented areas. The roadmap will also encourage IoT technology to be developed using protocols that allow seamless connectivity and facilitate reliable communications.

The rapid evolution of communications technology in recent history demonstrates the significant promise and opportunity for the nation to improve IoT connectivity. Current capabilities that were science fiction in the past are now routine in our daily lives. The U.S. must continue such advances to ensure that IoT can securely and reliably communicate and interoperate wherever devices are applied.

Pillar 4: Sustainability

Sustainability speaks to both environmental stewardship and to the ability to maintain continued use of IoT technology for a long time. Both are critical elements of effective IoT adoption.

In many cases, capital spending for IoT and associated technologies represents a significant investment that must provide benefits for decades. Retooling items like manufacturing equipment, municipal systems, and smart grid infrastructure can bring considerable benefits but must be well considered. To support such investments, it will be helpful to document the value proposition of comprehensive modernization that includes IoT technology and associated processes.

Building compelling business cases showing the value of increased efficiency and productivity from technical improvements will help propel organizations into the upcoming years.

A resilient and reliable supply chain is a prerequisite for this technology – as businesses and public-sector organizations come to depend upon the billions of devices that will form this IoT fabric, device manufacturers need to know that they have a reliable supply of materials, parts, and software. As with other areas, this concern represents both a challenge and an opportunity. Recent experiences with reduced availability of parts and supplies are teaching the nation to better manage our supply chain – from production to distribution to warehousing. As the nation better understands its reliance on external suppliers, it learns about opportunities to improve resilience and independence.

Recent history has also taught our nation to be more resilient in other ways and to be better stewards of the environment itself. All are gaining a new appreciation for the need to reduce the use of finite materials that are costly and bring environmental impact. Research into more practical solutions will help reduce costs, increase IoT availability, and improve stewardship.

Meanwhile, engineers continue to find new ways IoT can improve our environmental footprint. Smart technology can enhance ecological sustainability in many ways, such as monitoring environmental conditions, reducing the need for water and chemicals in farming, and automatically decreasing energy consumption. It is equally essential that the nation be cautious not to create new stewardship challenges by creating myriads of devices that end up in landfills. As the roadmap encourages expanded access to IoT for all, the nation should continue to promote accountability in recycling, responsible disposal, and maximized reuse of associated materials. IoT itself will not solve all environmental issues, but it may go a long way toward recording, monitoring, and addressing today's challenges.

As IoT improves sustainability for the nation – both technically and environmentally – it will measurably help ensure the reliability of critical infrastructure. The roadmap could explore monitoring and reporting capabilities (e.g., performance metrics, risk indicators) to help drive improvement.

Pillar 5: Workforce

Every aspect of IoT implementation depends on a trained and effective workforce, so the strategy for IoT adoption will focus on IoT training and education in order to increase not only capabilities but also to broaden the number of and diversity of people who are equipped to develop, provision, implement, and sustain IoT across sectors. This effort to ensure the scalability of personnel brings exciting opportunities to all areas of the country, from cities to farms to factories.

For instance, there is a vital need for engineers that will design the integrated circuits needed to create and evolve tomorrow's technology. The physical devices will rely upon software, communications, and interfaces that must operate faster, more securely, and more efficiently with every product life cycle. There is a significant need for seasoned workers, as well, as our nation learns how to transition from legacy to digital processes.

The recent U.S. focus on a diverse workforce provides a solid foundation for the IoT roadmap. Today's students and workers come from all walks of life, and they bring diverse experiences and perspectives that will be vital for the imaginative, innovative, and practical implementation of IoT technology. Some development and operations work can be performed remotely, further enhancing the ability to draw workers from areas of the country that have been underserved or those where major employers have left the region. These perspectives will help drive innovation and transformation, bolstered by advanced technologies for automation, data analytics, and information sharing.

Tomorrow's smart homes, factories and facilities will rely upon a broad pipeline of prepared workers that can implement technology, and on operators that can apply evolving technology. Therefore, the IoT roadmap will likely include specific actions to ensure that students and workers have the necessary knowledge and skills to perform the work to be done. These actions will also bring improved prosperity to many communities that have not previously enjoyed those benefits.

Pillar 6: Data Governance

As with other topics, data aspects of IoT present both challenges and opportunities. While the trust opportunities described in Pillar 1 are essential, it is equally important that the IoT roadmap support equitable access to the vast amounts of information that ubiquitous IoT will provide.

Some in the community have compared access to data with other valuable assets. Some U.S. regions historically gained economic benefits from the discovery of mineral resources like oil and gold – similar benefits could be achieved by “mining” and harvesting the vast information that data analytics provide. It is vital, however, that such use of information be conducted responsibly. As communities are learning from AI implementation, there must be safeguards to ensure that use of data is accurate, unbiased, and reliable.

Data will be used for vital decisions, many of which affect citizens’ lives and safety, so it must be well protected, maintained, and governed. Fortunately, this need presents additional opportunities for workforce development and management.

Unlike the “gold rush” and “oil boom” days of the past, where a limited region prospered, the nation has the opportunity to ensure broad and equitable access to data repositories, including those fed by vast networks of IoT devices. The IoT roadmap could stress the need for accessibility and data transparency.

Recommendations will highlight the need to ensure provisions for protecting how IoT-derived data is stored, shared, protected and deleted when no longer needed, including anonymization and privacy, in alignment with the Trust Pillar.

The ability to access and fuse different real-time data sources already provide benefits, such as supporting improved crash prevention and mobility in transportation. Safe and equitable access to large pools of data could bring additional benefits to the nation – perhaps revolutionary cures based on healthcare findings, production innovation based on manufacturing data, or imaginative agriculture solutions.

By providing incentives and requirements for fair and equitable access to safe, protected data repositories, new opportunities for citizens around the country will emerge. The diversity of the data types may also drive some sector-specific considerations and possibilities.

Pillar 7: Adjacent Technologies

IoT is supplemented and supported by an array of adjacent technologies such as AI and “big data analytics”. As the vast fabric of IoT collects data in near real-time, AI and analytic engines interpret results and provide actionable information, which are then acted on within the IoT ecosystem. The two technologies are converging to provide even more benefits to the adopters of IoT technologies. Blockchain is another example of an adjacent technology that can support scalability, security, and traceability of the IoT. The roadmap recognizes that IoT success requires a comprehensive solution that leverages these overlapping technologies safely and responsibly.

One example of an overlapping solution is the notion of "digital twins". The use of digital information to simulate and represent some physical object or system continues to expand and enables significant research. This approach supports other pillars, as well. Creation, operation, and maintenance of digital twin simulation reduce the cost and burden of creating physical replicas for researching and achieving improved sustainability. Data produced and available to a diverse and distributed workforce provides opportunities in underserved areas and communities. Lessons learned from such work enable other communities to accelerate their own research and development actions.

It is likely that many other adjacent technologies will help accelerate IoT adoption by working together. Wider availability of Wireless Power Transfer, for example, could help to address anticipated issues surrounding IoT device maintenance relating to battery replacement or charging high volumes of IoT devices. Strategic pillars, like physical pillars for a structure, share the workload to ensure resilience, trust, and sustainability. Operational Technology IoT leads the way for efficient and sustainable infrastructure and operations. An important element of the IoT roadmap for national IoT adoption could be understanding ways to weave various technologies together into a tapestry that improves interoperability, supports national priorities, and enhances resilience.

Your feedback is valuable: Broad stakeholder feedback about these pillars will inform IoTFWG's report to Congress. Which recommendations on these pillars will help achieve the economic and societal benefits IoT promises? Are there additional pillars (or changes to these pillars) that readers recommend? What monitoring and reporting capabilities (e.g., performance metrics and risk indicators) will help drive improvement?

Mechanisms for Supporting IoT Pillar Adoption

The IoTFWG is identifying specific and practical ways to enable IoT adoption. The following mechanisms provide examples of actions that the U.S. can begin or expand to achieve the vision described in our Strategic Pillars, helping to accelerate progress toward the benefits above.

- **Government-based / cooperative research and development** – federally funded research programs are a key mechanism for discovering, improving, and advancing IoT technology. In addition to R&D programs within agencies, collaborative partnership (e.g., with public/private sectors, academia) brings exciting opportunities for progress on strategic pillars.
- **Federal technology transfer** – in line with the research described above, agencies often seek ways to share knowledge, skills, methods, and technologies with others that can further develop capabilities. Many products and technologies foundational to IoT (including the Internet itself) began as government projects. Agencies can work with partners to seek ways to jointly develop or to license research results for commercial development of new products from which all will benefit. The government can also fund a university or a federally funded research and development center (FFRDC) to develop a technology and subsequently license it to a company for inclusion in a product.
- **Government-based outreach and engagement** – agencies can engage with the public about improvements, recommendations, and opportunities to address known IoT challenges and enhance opportunities. Federal support and encouragement of community members in many industry sectors will help them to be primary adopters of IoT technology. An example approach might be through a community extension partnership similar to the highly-successful U.S. Department of Agriculture Cooperative Extension Services and the NIST Manufacturing Extension Partnership (MEP).
- **Federal support for workforce training** - preparing learners to develop, implement, secure, and operate IoT technology will greatly help the nation to achieve IoT's economic and societal benefits. As it has done for other types of technical needs (e.g., cybersecurity), the government can help standardize, improve, and promote successful training initiatives. Technology changes rapidly, so federal coordination will

help enable learners at all levels in all industries to understand the evolving skills and knowledge needed for successfully applying and improving IoT technology.

- **Federal coordination** - as agencies expand adoption of IoT and work with nonfederal entities to fulfill IoT recommendations, extensive coordination will be necessary. Interagency collaboration is vital, as well. Examples of coordination types may include resource sharing, knowledge repositories, and cooperative projects.

- **Government-based grants** - benefits from IoT often depend upon initial investments that are difficult for small businesses and municipalities to afford. Through grants and partnerships, the government may be able to kickstart the implementation of IoT solutions, leading to significant benefits for businesses; state, local, and tribal government entities; and consumers. In economically disadvantaged communities, grants to enable sustainment may also be needed.

- **Federal guidance/policy** - clear, consistent policy with supporting guidance is an important building block. Policy underlies much of the connectivity and interoperability described, so the roadmap could identify necessary policies (or updates to existing ones) to support reliable, equitable IoT deployment. Clear guidance can provide awareness and consistent implementation in various technical and societal areas.

Are there mechanisms that should be added? What methods should the Federal Government include to implement the pillars above?

Conclusion

The U.S. has a unique opportunity to advance its social and economic prosperity through improved adoption of IoT technology. The U.S. Congress has recognized the need for a roadmap or strategy promoting IoT solutions for use across the country which are secure, scalable, interoperable, industry-driven, and standards-based.

Doing so will maximize IoT benefits to all stakeholders, including businesses, governments, and consumers. The IoTFWG, as part of a comprehensive and collaborative process, will continue to develop strategic recommendations for Congress. Public feedback is welcomed regarding benefits, enabling mechanisms, and challenges. By improving and expanding the Internet of Things adoption, the U.S. will enjoy significant economic benefits, improved efficiency of operations, and exciting innovations across the nation.