Interoperability and the Internet of Things

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Interoperability and the Internet of Things

The Internet of Things (IoT) is growing exponentially. Government, businesses, and individuals all rely on technology and devices to improve efficiency, increase security, and improve daily life. Interoperability is accelerating IoT innovation and adds value to IoT devices. Less than a decade ago, mainstream connected cars and smart appliances seemed like a distant reality. The exponential growth is due largely to interoperability and open source software. Interoperability is the ability for unique devices (such as smart phones, home monitoring system, and thermostats) to share data and interact with one another. Open source is software with publicly available source code, so anyone can rewrite or adapt the code. Open source has been indispensable to the growth of IoT because when software is written in the same publicly available language, it makes it easier to develop devices that interact.

In order to explore the contribution of interoperability to IoT holistically, we examine software developers and IT companies that are fueling IoT growth and the products they create. We start by looking at the number of software developers and the programming languages they use to develop interoperable products. We then examine two key IoT markets, Home and Auto IoT, to estimate the contributions of interoperability and consequently the cost of restricting this access on the growth potential of IoT.

Software developers use common languages, like Java, to create open source software

The most recent estimate of software developers is over 21 million people globally.[1] Prior research has estimated that developers include two major subcategories: professionals (59.5%) and hobbyists (40.5%).[2] We estimate there are 4.1 million developers in the U.S., accounting for 20% of global software developers. Using official data published by the U.S. Bureau of Labor Statistics, we estimate there are nearly 3 million professionals that are involved in software development and programming as part of their job. Over half of those are strictly software developers while the rest have occupations that require programming as a secondary component of their work such as computer scientists, data analysts, and database administrators. Other 1.2 million software developers are falling into the category of hobbyist.

Software developers are often skilled in multiple common programming languages such as Java, C++, and Python. In an analysis of Indeed data in 2017, 94% of job postings required more than one programming language and 44% required more than five programming languages.

DEVELOPERS

IN THE U.S.

4.1 M

Of the 4.1 million developers in the U.S., about 42% use Java. However, for IoT developers, the share is more than 60%.

[1] Evans Data Corporation. 2017. Global Developer Population and Demographic Study 2017 Vol. 1.
[2] IDC. 2014. Global Software Developers.

Table 1.

US Employers Look to Hire Developers Who Are Familiar with Several Programming Languages[3]

Number of Programming Languages Desired	Share of Job Postings
One	6%
Two to Three	22%
Four to Five	29%
Six to Eight	25%
More than Eight	19%

Java is among the most popular programming languages posted for developers, with 42% of job postings specifically listing the programming language in the job posting. We use this demand to estimate the number of developers that use Java. We estimate approximately 1.6 million software developers in the U.S. and 8.8 million software developers globally use Java.

Table 2.

US Developers that Use Java[4]

	Developers	Java Users
Professionals	1,604,570	1,236,728
Primary: Software Developers	1,340,020	
Secondary: Computer Scientists, Data Analysts & Database Administrators	2,944,590	
Hobbyists	1,193,753	501,376
Total Developers	**4,138,343**	**1,738,104**

Notably, Java is even more common for developers working on IoT and open source projects. A recent survey found that, in 2017, 61% of developers use Java to build IoT solutions, up from 52% in 2016.[5] In terms of utilizing open source software, Java is the second most popular programming language (out of 316 programming languages) for open source software accessed on Github, the world's largest software

[3] ndp | analytics analysis of Indeed.com data.
[4] BLS. 2016. Occupational Employment Statistics; ndp | analytics analysis of Indeed.com job postings.
[5] Eclipse et al. 2017. IoT Developer Survey. https://www.slideshare.net/IanSkerrett/iot-developer-survey-2017; Eclipse et al. 2016. IoT Developer Survey. https://www.slideshare.net/IanSkerrett/iot-developer-survey-2016

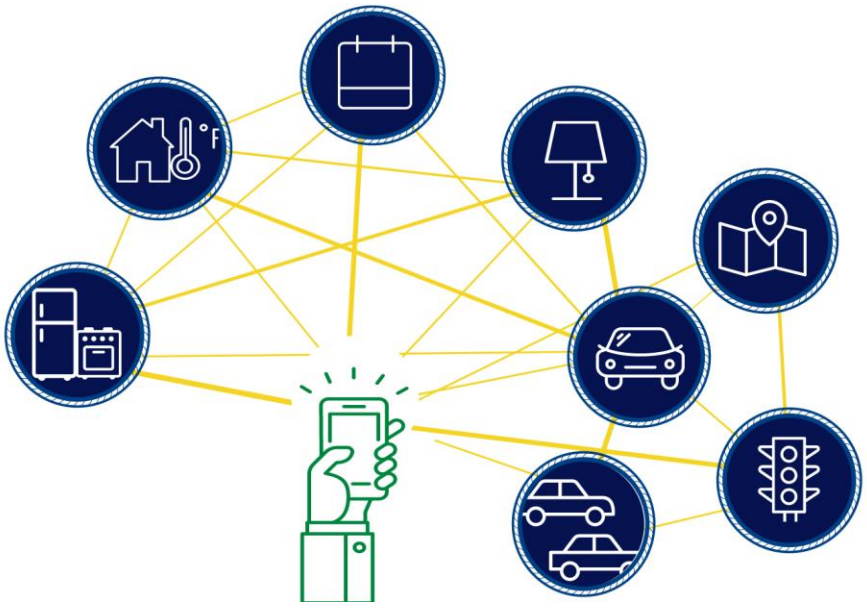
repository, second only to JavaScript.[6] As a result, it is expected that a large share of IoT software can be traced back to open source programs written using Java.

Open source software enables interoperability

Today, developers rely on open source to develop new products and services. In fact, community open source software is embedded in nearly all commercially relevant software today, open or closed source.[7] There are several notable benefits of open source software:[8]

1) Reliability: Since open source software is widely tested and used, open source software is often more reliable than proprietary software.
2) Cost effectiveness: Open source software are often accessed at no cost whereas proprietary software could be expensive to create and test.
3) Robustness: Open source software is a product of collaboration. Continued advancement and collective brainstorming helps open source software to keep up with the latest technology.

Importantly, open source software is so popular within IoT because it easily enables interoperability. The use of common code makes it easier for devices to "talk" to one another, and open platforms have been developed maximize this communication.



INTEROPERABILITY

allows devices to collect data and communicate with other devices in real time, without human intervention

[6] https://octoverse.github.com/
[7] Riehle, Dirk. 2015. How Open Source Is Changing the Software Developer's Career. IEEE
[8] Almeida, Fernando, José Oliveira, and José Cruz. 2011. Open Standards and Open Source: Enabling Interoperability. International Journal of Software Engineering & Applications (IJSEA), Vol.2, No.1, January.

Interoperability fuels IoT innovation

Interoperability is a fundamental element of IoT growth. McKinsey Global Institute estimates IoT will produce over $11 trillion globally per year by 2025, and up to 40% is expected to be derived from interoperability.[9] In this report, we focus on two important and fast growing sub-sections of consumer IoT: Auto IoT (connected cars) and Home IoT (e.g., monitoring systems and connected devices). Both of these segments are expected to generate significant value to U.S economy and users in the next 10 years.

Auto IoT

The IoT transforms the way we travel. About 98% of American workers commute in personal or employer supplied vehicles. AAA estimated that Americans spent an average of 17,600 minutes (equivalent to 290 hours) on the road over the course of the year.[10] While autonomous vehicles are still in the testing phase, connected cars are already on the commercial market. Vehicle communications technology has transformed from car phones and portable GPS navigation systems to the "On Star" call button, to fully integrated, hands-free, voice commanded communication and navigation systems. Through the interaction between IoT devices such as smart phones, connected car components, and applications, consumers will realize significant cost and time savings. Importantly, these advancements are also expected to improve safety and reduce the environmental footprint from vehicles.

The Auto IoT landscape includes auto manufacturers such as Telsa, Audi, General Motors, and Ford, established technology companies like Google, Apple, Intel, Amazon, and Android, and a wide variety of start-ups. In the last five years, over $14.5 billion has been invested in IoT companies that focus on auto IoT. During this time, 34 companies have received $50 million or more in funding to advance their ride sharing, autonomous vehicles, energy savings, and navigation technologies.[11] Many of these companies become well-known, such as Uber, Waymo (Google's Self Driving Cars), and Waze App. Others are still emerging. Zoox, an autonomous vehicle software company, is becoming a big player in this space; having received $260 million in funding to date.[12] Chargepoint has received over 290 million in funding and is the largest network of electric vehicle charging stations.[13]

[9] McKinsey Global Institute. 2015. The Internet of Things. Mapping the Value beyond the Hype
[10] AAA. 2016. American Driving Survey 2014-15. https://www.aaafoundation.org/sites/default/files/AmericanDrivingSurvey2015.pdf
[11] Spoke Intelligence and Readwrite. 2017. The IoT Revolution Landscape. https://drive.google.com/file/d/0B2gI-_SP5WmzMVcxVFZDTnlCX3c/view?submission=293902691
[12] Crunchbase database. https://www.crunchbase.com/organization/zoox
[13] Crunchbase database. https://www.crunchbase.com/organization/chargepoint#/entity

Auto IoT Market

In 2015, approximately 50% of new cars sold had some sort of communications capabilities such as embedded, tethered, or smart phone integration and about 20% had embedded connectivity solutions.[14] A year later, 24% of cars shipped were connected. We estimate that $137.7 billion of U.S. light vehicle sales in 2016 were connected cars. Five year projections vary from 82% to 98% for the number of connected cars expected as a share of total car shipments in five years.[15] To be conservative, we assume that 82% of cars shipped are connected and that in the U.S. the number of new vehicles sold is expected to remain fairly constant. Assuming a 1.1% decline based on current forecasts, we estimate the connected market will quadruple to $515 billion inflation-adjusted by 2021.

AUTO IoT

CONNECTED CARS

82% of new cars will be have communications capabilities by 2020.

In addition to the number of vehicles sold, the market for hardware, vehicle services, and infotainment is also seeing significant growth. Statista, a market research firm, estimates that hardware that allows vehicles to communicate, cost of vehicle related services, and fees for infotainment generated $5.8 billion in 2016 ($5.2 billion of which was generated by connected hardware). Statista estimates this revenue to increase to $18.1 billion by 2021. As a result, the combination of new connected vehicle sales and other connected car hardware, vehicle services and infotainment market is estimated to be about $143.5 billion in 2016 and $533.0 billion by 2021 (Table 3).

Table 3.

U.S. Connected Car Market 2016 and 2021[16]

	2016 *($ Billions)*	2021 *($ Billions)*	Percent Increase
New Connected Vehicle Sales	$137.7	$514.9	274%
Other Auto IoT	$5.8	$18.1	212%
Total	**$143.5**	**$533.0**	**272%**

[14] Forbes. 2015. Connected Cars. https://blogs-images.forbes.com/niallmccarthy/files/2015/01/connected_cars_forbes.jpg

[15] BI Intelligence. 2016. Automotive Industry Trends: IoT Connected Smart Cars & Vehicles. http://www.businessinsider.com/internet-of-things-connected-smart-cars-2016-10; Statista. 2015. Share of new cars sold that are connected to the Internet worldwide from 2015 to 2025 https://www.statista.com/statistics/275849/number-of-vehicles-connected-to-the-internet/

[16] ndp | analytics analysis of statics from U.S. Bureau of Economic Analysis, National Automobile Dealers Association, BI Intelligence, and IHS Markit.

Other Economic Impacts

The economic impact of Auto IoT goes beyond revenue. It includes time and cost savings to consumers in terms of insurance premiums, traffic avoidance, and accident avoidance, among others. An average commuter in a metropolitan area loses 63 hours per year (over 2.5 days) because of traffic congestion at an estimated cost of $1,433 per commuter.[17] Additionally, the National Highway Safety Administration reported that 94% of vehicle accidents in the U.S. are attributed to drivers themselves.[18] Auto IoT is improving the way we commute, and increasing safety through collecting data on maintenance and driver habits, enabling vehicle to vehicle communications, and collision prevention. To fuel this innovation, auto companies are partnering with technology companies to develop interoperable connectivity to the next generation of connected cars. For example, BMW announced a partnership with IBM Watson in late 2016 to develop "intelligent assistance functions" that allow drivers and passengers to communicate with the vehicle, and the vehicle to predict behavior, based on artificial intelligence.[19]

In a review of over 300 IoT applications and use-cases, McKinsey Global Institute (MGI) estimates the global impact of IoT to be over $11 trillion per year by 2025. The benefits created by vehicles alone are between $210 and $740 billion, largely due to in condition-based maintenance and changes in insurance premiums.[20]. Of this, $153 to $572 billion is attributable to passenger vehicles.

AUTO IoT

IMPACT OF INTEROPERABILITY

$16.1 billion

to

$60.3 billion

Advanced economies capture 63% of the economic impact of auto IoT ($96 to $360 billion). The International Monetary Fund classifies advanced economies based on three criteria: income per capita, integration into the global financial system, and diversified exports.[21] Advanced economies capture a larger share of the benefits of IoT than developing countries because they have higher incomes and more advanced infrastructure to support IoT capabilities. The U.S. accounts for about 38% of GDP for advanced economies. Using this share, we estimate that the U.S. will capture between $50.8 and $107.1 billion in economic efficiencies. Of this, $28.5 to $32.2 billion is realized from improved safety and reduced insurance costs, $19.2 to $63.7 billion is from cost savings from reduced maintenance and longer lifespans of vehicles, and $3.0 to $11.2 billion is from productivity gains.

Interoperability is crucial to the success of auto IoT. Vehicles must be able to interact with other vehicles, as well as communications and mapping systems, and transportation infrastructure to capture all benefits. MGI

[17] Texas A&M. 2015. National Congestion Tables and Trends, 2014. https://mobility.tamu.edu/ums/national-congestion-tables/
[18] U.S. Department of Transportation National Highway Traffic Safety Administration. 2015. Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey
[19] Guerrini, Federico. 2016. BMW Partners With IBM To Add Watson's Cognitive Computing Capabilities To Its Cars. Forbes. December 15. https://www.forbes.com/sites/federicoguerrini/2016/12/15/bmw-partners-with-ibm-to-add-watsons-cognitive-computing-capabilities-to-its-cars/#fa84d751a908
[20] McKinsey Global Institute. 2015. The Internet of Things. Mapping the Value beyond the Hype.
[21] International Monetary Fund. FAQ: WEO Country Groups and Purchasing Power Parity (PPP). https://www.imf.org/external/pubs/ft/weo/faq.htm#q4b

estimates that 44% of the economic impact is due to interoperability. We apply this share to estimate the total impact of interoperability of vehicles in the U.S. to range from $16.1 billion to $60.3 billion.

Table 4.

Impact of Auto IoT and Interoperability, 2025[22]

	Low Estimate *($ Billions)*	High Estimate *($ Billions)*
Impact of Auto IoT	$36.7	$137.1
Impact of Interoperability	$16.1	$60.3

Home IoT

Smart home technology presents endless opportunities. In tomorrow's connected home, IoT devices will know when your alarm goes off in the morning; when you press snooze, the coffee maker will automatically turn on, and the lights will start to gradually turn on, and the thermostat will know to adjust to its "away" in 90 minutes, after you have left for work. Some of today's most popular products already allow users to do a combination of those things, and more, such as control lighting and temperature remotely, monitor home security systems and reduce food and water waste, and energy use with smart appliances. According to recent research, 26% of internet users own a smart home product or device, and only 15% plan to purchase one in the next year.[23] As a result, there is significant opportunity for growth in Home IoT Market.

The Home IoT landscape is very diverse. The industry includes home products manufactures for appliances, electronics and other products (e.g., GE, Vizio, and Belkin), security companies (e.g., ADT), large technology companies (e.g., Amazon, Google, and Apple), and small start-ups. Since 2013, $3 billion has been raised for new home IoT companies, with 23 companies receiving $50 million or more.[24] While the first connected appliance was launched in 2000 by LG, smart appliances have been slower to take off than other Home IoT products. Some of the most popular products are related to security and energy, including home monitoring systems, and smart door locks. For example Nest, the connected thermostat start-up, was acquired by Google while August, a smart lock start-up, has received over $70 million in funding. There are also open source platforms like Eclipse Smart Home that allows consumers to monitor and control their home devices in one place.[25]

[22] ndp | analytics analysis of McKinsey Global Institute and World Bank data.
[23] PwC. 2017. Smart home, seamless life.
[24] Spoke Intelligence and Readwrite. 2017. The IoT Revolution Landscape. https://drive.google.com/file/d/0B2gI-_SP5WmzMVcxVFZDTnlCX3c/view?submission=293902691
[25] Postscapes. 2017. Home IoT Guide. https://www.postscapes.com/internet-of-things-award/connected-home-products/

Home IoT Market

The IoT Market includes smart appliances, energy management systems, home automation, security systems, entertainment, and ambient assisted living (e.g. emergency buttons, fall sensors, and smart scales). In total, we estimate the U.S. Home IoT market totaled $10.4 billion in 2016 and expect to triple to $32.2 billion by 2021. The biggest 2016-2021 growth is expected in home security (288%) and ambient assisted living devices (517%).

Like Auto IoT, consumers realize economic benefits such as cost-savings and improved productivity through Home IoT technology. On average, Americans spend 664 hours a year (nearly 28 days) on household activities (i.e., chores, cooking, and lawn care) and 277 hours a year purchasing goods and services (nearly 12 days).[26] Home IoT transforms the way we do daily tasks and monitor our homes. Some of the most innovative products in development include Innit, a smart cooking system that can detect what is being made and adjust the temperature and cooking time, to Jibo and Rokid which are essentially robots that provide home maintenance and assistance. Popular products already on the market include smart thermostats, like Nest, and home security systems that notify users of potential issues (smoke alarm or unauthorized entry) and allow users to check in remotely through mobile apps.

HOME IoT

OPPORTUNITIES TO INCREASE EFFICENCY

Americans spent at total of about 28 days doing chores, and 12 days shopping. IoT

Table 5.

U.S. Smart Home Market 2016 and 2021[27]

	2016 *($ Billions)*	2021 *($ Billions)*	Percent Increase
Appliances	$6.6	$16.4	149%
Home Automation	$3.8	$9.2	145%
Security	$2.8	$11.1	289%
Home Entertainment	$1.9	$5.7	193%
Energy Management	$0.4	$2.3	517%
Ambient Assisted Living	$1.5	$4.0	162%
Total	**$15.5**	**$44.6**	**188%**

[26] Bureau of Labor Statistics. 2017. American Time Use Survey, 2016.
[27] ndp | analytics analysis of statics from Statista and ZPrime.

Other Economic Impacts

MGI estimates that home IoT will generate between $200 and $350 billion globally in 2025 in energy management, chore automation, security, and usage-based design of appliances. Advanced economies capture 77% ($154 to $269 billion) of this impact, because of the higher disposable income and advanced infrastructure required for Home IoT products. The U.S. accounts for about 38% of GDP among advanced economies. Using this share, we estimate that the U.S. will capture between $58.6 and $102.5 billion in economic efficiencies, of which $35.9 to $62.8 billion is realized in time savings, $16.4 to 28.7 billion is realized through energy savings and $6.3 to $11.0 billion in other benefits including improved home security and value added from smart appliances. We consider this estimate conservative because Americans have more IoT devices online than most other countries (behind South Korea, Switzerland and Denmark), and is likely to capture more benefits because of its higher adoption rate.[28]

In order to capture the maximum value and consumer surplus from home IoT technologies, consumers must be able to control and monitor devices from a common platform. The benefits of interoperability for home IoT are the productivity gains, energy savings and cost savings from ability to link chore automation to energy usage to security monitoring systems. In total, these benefits account for 17% to the total impact of Home IoT. We estimate the impact of interoperability for home IoT devices in the U .S. to range between $10.0 billion and $17.4 billion annually in 2025.

IMPACT OF INTEROPERABILITY

$10.0 billion

to

$17.4 billion

Table 6.

Annual Impact of Home IoT and Interoperability, 2025[29]

	Low Estimate *($ Billions)*	High Estimate *($ Billions)*
Impact of Home IoT	$58.6	$102.5
Impact of Interoperability	$10.0	$17.4

Conclusion

Open source is crucial to IoT growth. Open source easily enables interoperability. Interoperability is the key to the value and success of IoT. In fact, it accounts for billions of dollars of the expected value of IoT. If access to open source is restricted, it will be more costly and complicated to enable interoperability between devices. Notably, 44% of Auto IoT and 17% of Home IoT is derived from interoperability, respectively. In a home,

[28] Atlas. Countries with the most IoT devices, Devices online per 100 people. Available: https://www.theatlas.com/charts/E1VUy4z0x

[29] ndp | analytics analysis of McKinsey Global Institute and World Bank.

Interoperability and the Internet of Things

Interoperability allows a user to manage multiple devices such as a thermostat, kitchen appliances, and security system from the same platform, and have the devices interact with each other; if the stove in the kitchen is being used, the thermostat can adjust automatically. It is this type of functionality that will maximize cost and time savings. Auto IoT manufacturers and technology companies are collaborating to create open source software that will allow vehicles from separate manufacturers to interact with each other. This functionality will maximize safety and reduce energy costs for those using vehicles.

In sum, all the excitement around IoT is fueled by the ability for devices to interact with each other. For the U.S. to encourage the most innovation and derive the most value from IoT, developers must have access to open source software.

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