



# **Quantifying Risks to Interoperability in the Software Industry**

**A Report by the Developers Alliance & NDP Analytics**

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## Introduction

Developers are the workforce of the 21<sup>st</sup> Century. Rather than assembling machine parts, developers assemble code, the language of machines, devices, automation, and networks. There are 21 million developers working on almost 60 million projects,<sup>1</sup> with projections for even more growth in the coming decade. Like their 20<sup>th</sup> century counterparts in manufacturing and farming, the key to developer success is in mastering the tools of their trade. More and more this means a deep understanding of a few foundational computer languages that underpin the software industry.

The growth of the developer workforce and the growth of applications that require coding go hand-in-hand. The future of the technology industry goes far beyond the computer screen or the mobile device. It's in the "things" that are used every day, whether by consumers or professionals, from the most commonly used household items to the complex tools of hyper-niche professions. The value of these devices is increasingly enabled in by their ability to communicate and interact with one another. Devices that require code and talk to one another are not just common, they're the standard. This provides a foundation for future innovation.

The future of the developer workforce is outside the technology industry, although more and more businesses are labeling themselves as "technology companies" nowadays. The world's most innovative companies and organizations, regardless of industry, are embracing next-generation technologies, tools, and platforms to transform and disrupt traditional marketplaces. Software developers and the code they write are the path to competing in the digital age.

Broadly speaking, the technology that connects these devices is referred to as **the Internet of Things (IoT)**, and it is one of the largest sources of growth, excitement, and investment in the technology industry. What makes IoT possible is **interoperability** between the software and hardware from hundreds of companies inside millions of devices. Software interoperability is the glue that holds the complex IoT ecosystem together, and the building blocks of interoperable software come from the open source movement. Community open source software is embedded in nearly all commercially relevant software today.

Despite being so ingrained in how the IoT industry operates, the interoperability IoT devices rely on is at risk. Specifically, there is a troubling trend of litigation in cases that seek to upend the economics of software development by impugning the concept of software interoperability and allowing companies that control languages or APIs to charge developers for, or prevent them from, making compatible software.

In the event of diminished or extinguished interoperability, perhaps due to a court's decision, we estimate **\$77 billion** in economic productivity over the next eight years is at risk, on top of myriad additional indirect economic consequences. This report examines those consequences, along with the threats that would set them in motion.

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<sup>1</sup> Evans Data Corporation. 2017. Global Developer Population and Demographic Study 2017 Vol. 1.

## Open source software enables interoperability, which fuels IoT innovation

IoT represents a tectonic shift in the future of technology and software development. The smartphone penetration rate in the United States is already over 80%.<sup>2</sup> Future growth will be contained in other objects that Americans use every day such as watches and other wearables, and sensors and devices in their house, at their work, in their car, and in public spaces. 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.<sup>3</sup>

Developers rely on open source to develop new products and services. Community open source software is embedded in nearly all commercially relevant software today, even in closed source applications.<sup>4</sup> There are several notable benefits of open source software:<sup>5</sup>

- 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 is often accessed at no cost, whereas proprietary software is often expensive to create and test.
- 3) **Robustness:** Open source software is a product of collaboration. Continued advancement and collective brainstorming helps open source software keep up with the latest technology.

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

In this report, we focus on two important and fast growing sub-sections of consumer IoT: Auto IoT (e.g. connected cars) and Home IoT (e.g. monitoring systems and connected devices). Both of these segments are expected to generate significant value to the U.S. economy and users in the next 10 years.

### Auto IoT

Around 98% of American workers commute in personal or employer supplied vehicles, making Auto IoT a highly visible vertical. AAA estimated that Americans spent an average of 17,600 minutes (equivalent to 290 hours) on the road over the course of the year.<sup>6</sup> 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

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<sup>2</sup> comScore. 2017. U.S. Smartphone Penetration Surpassed 80 Percent in 2016.

<sup>3</sup> McKinsey Global Institute. 2015. The Internet of Things. Mapping the Value beyond the Hype.

<sup>4</sup> Riehle, Dirk. 2015. How Open Source Is Changing the Software Developer’s Career. IEEE

<sup>5</sup> 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.

<sup>6</sup> AAA. 2016. American Driving Survey 2014-15.

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 Tesla, Audi, and Ford; established technology companies like Google, Apple, 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.<sup>7</sup> Many of these companies become well-known, such as Uber, Google Self Driving Cars, and the 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.<sup>8</sup> Chargepoint has received over \$290 million in funding and constitutes the largest network of electric vehicle charging stations.<sup>9</sup>

### Home IoT

The most tangible IoT devices are smart appliances in your home – a “smart fridge,” security system, or the thermostat that you can control with your mobile device. Entire “smart homes” have been on the market for years, and savvy shoppers can piece together their own smart home one appliance at a time.

Smart home technology presents endless opportunities. IoT devices control lighting and temperature remotely, monitor home security systems, and reduce food and water waste, and energy use with smart appliances. Some of today’s most popular products already allow users to do a combination of those things and more. According to recent research, 26% of internet users own a smart home product or device, and another 15% plan to purchase one in the next year.<sup>10</sup>

The Home IoT landscape is very diverse, including home products manufacturers for appliances, electronics, security systems, and other products, made by the largest technology companies as well as small start-ups. Since 2013, \$3 billion has been raised for new home IoT companies, with 23 companies receiving \$50 million or more.<sup>11</sup>

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 (acquired by Google) and August, a smart lock start-up, has received over \$70 million in funding. There are also open source platforms like Eclipse Smart Home and OpenHab that offer a way for consumers to monitor and control their home devices in one place.<sup>12</sup>

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<sup>7</sup> Spoke Intelligence and Readwrite. 2017. The IoT Revolution Landscape.

<sup>8</sup> Crunchbase database. <https://www.crunchbase.com/organization/zoox>.

<sup>9</sup> Crunchbase database. <https://www.crunchbase.com/organization/chargepoint#/entity>

<sup>10</sup> PwC. 2017. Smart home, seamless life.

<sup>11</sup> Spoke Intelligence and Readwrite. 2017. The IoT Revolution Landscape.

<sup>12</sup> Postscapes. 2017. Home IoT Guide.

## Economic impact of IoT

In order to explore the contribution of interoperability to the IoT holistically, we examined software developers, IT companies, and the products they create that are fueling IoT growth. 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 – Auto and Home IoT to estimate the contributions of interoperability and consequently the cost of restricting this access on the growth potential of IoT.

### *Auto IoT Market*

In 2015, about 50% of new cars sold had some sort of communications capabilities such as embedded, tethered, or smartphone integration and about 20% had embedded connectivity solutions.<sup>13</sup> A year later, 24% of cars shipped had connectivity solutions. We estimate that \$137.7 billion of U.S. light vehicle sales in 2016 were connected cars. The number of connected cars as a share of total car shipments by 2020 and 2021 varies from 82% to 98%.<sup>14</sup> 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 that the connected market will quadruple to \$515 billion by 2021, adjusted for inflation.

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.<sup>15</sup>

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 1).

Table 1.

### U.S. Connected Car Market 2016 and 2021<sup>16</sup>

\$B	2016	2021	% Increase
<b>New Connected Vehicle Sales</b>	\$137.7	\$514.9	274%
<b>Other Auto IoT</b>	\$5.8	\$18.1	212%
<b>Total</b>	<b>\$143.5</b>	<b>\$533.0</b>	<b>272%</b>

<sup>13</sup> Forbes. 2015. Connected Cars.

<sup>14</sup> BI Intelligence. 2016. Automotive Industry Trends: IoT Connected Smart Cars & Vehicles.

<sup>15</sup> Statista. 2015. Share of new cars sold that are connected to the Internet worldwide from 2015 to 2025.

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

### *Extended Auto IoT Impact*

The economic impact of Auto IoT goes beyond revenue. It includes time and cost savings to consumers in terms of insurance premiums, traffic 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.<sup>17</sup> Additionally, the National Highway Safety Administration reported that 94% of vehicle accidents in the U.S. are attributed to drivers themselves.<sup>18</sup> Auto IoT is improving the way we commute, and increasing safety through collecting data on vehicle 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.<sup>19</sup>

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 over the same time frame, largely due to in condition-based maintenance and changes in insurance premiums. Of this, \$153 to \$572 billion is attributable to passenger vehicles.

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.<sup>20</sup> 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. That breaks down as follows: \$28.5 to \$32.2 billion is realized from improved safety and reduced insurance cost; \$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 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.

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<sup>17</sup> Texas A&M. 2015. National Congestion Tables and Trends, 2014.

<sup>18</sup> U.S. Department of Transportation National Highway Traffic Safety Administration. 2015. Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey

<sup>19</sup> Guerrini, Federico. 2016. BMW Partners With IBM To Add Watson's Cognitive Computing Capabilities To Its Cars. Forbes. December 15.

<sup>20</sup> International Monetary Fund. 2017. FAQ: WEO Country Groups and Purchasing Power Parity (PPP).

Table 2.

Impact of Auto IoT and Interoperability, 2025<sup>21</sup>

\$B	Low Estimate	High Estimate
<b>Impact of Auto IoT</b>	\$36.7	\$137.1
<b>Impact of Interoperability</b>	\$16.1	\$60.3

*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). We estimate the U.S. Home IoT market totaled \$10.4 billion in 2016 and expect to be triple to \$32.2 billion by 2021. The biggest 2016-2021 growth is expected in home security (288%) and ambient assisted living devices (517%).

Table 3.

U.S. Smart Home Market 2016 and 2021<sup>22</sup>

\$B	2016	2021	% Increase
<b>Appliances</b>	\$6.6	\$16.4	149%
<b>Home Automation</b>	\$3.8	\$9.2	145%
<b>Security</b>	\$2.8	\$11.1	289%
<b>Home Entertainment</b>	\$1.9	\$5.7	193%
<b>Energy Management</b>	\$0.4	\$2.3	517%
<b>Ambient Assisted Living</b>	\$1.5	\$4.0	162%
<b>Total</b>	<b>\$15.5</b>	<b>\$44.6</b>	<b>188%</b>

*Extended Home IoT Impact*

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).<sup>23</sup> Home IoT transforms the way people do daily tasks and monitor their 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

<sup>21</sup> ndp | analytics analysis of McKinsey Global Institute and World Bank data.

<sup>22</sup> ndp | analytics analysis of statics from Statista and ZPrime.

<sup>23</sup> Bureau of Labor Statistics. 2017. American Time Use Survey, 2016.



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.

McKinsey 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 in 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 only South Korea, Switzerland and Denmark), and are likely to capture more benefits because of its higher adoption rate.<sup>24</sup>

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.

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Table 4.

Annual Impact of Home IoT and Interoperability, 2025<sup>25</sup>

\$B	Low estimate	High estimate
<b>Impact of Home IoT</b>	\$58.6	\$102.5
<b>Impact of Interoperability</b>	\$10.0	\$17.4

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<sup>24</sup> Quartz. 2017. Coming Soon: The Internet of Clothes.

<sup>25</sup> ndp | analytics analysis of McKinsey Global Institute and World Bank.



## Industrial IoT

Perhaps the biggest growth area – and where IoT has transformed and disrupted traditional marketplaces the most – is in Industrial IoT (IIOT). In the span of a decade, Industrial IoT has upended century-old ecosystems. As connected devices become more commonplace in the home and car, industrial customers will have higher and higher expectations for connectivity, from manufacturing to energy to agriculture to infrastructure to health care.

The Industrial IoT market was sized at \$109 billion in 2016, and is expected to reach almost \$1 trillion by 2025.<sup>26</sup> By the year 2030, IIoT could add \$14.2 trillion to the global economy.<sup>27</sup> Investments in IIoT start-ups has grown year after year since 2013, reaching over \$2.2 billion in investments in 2016.<sup>28</sup>

The Developers Alliance does not have an estimate on the impact of interoperability to the Industrial IoT market, so this sector is not included in this report's overall economic impact, which looks solely at home and auto IoT.

### Risks to interoperability that fuel IoT

There will be 8.4 billion connected devices and products in use across the world this year according to Gartner,<sup>29</sup> a 31% increase from 2016. More and more devices are coming online and connecting to one another, seemingly at such a rate that it's impossible to imagine the trend slowing or reversing. However, there are real risks that threaten the growth and economic potential of IoT.

The underpinning of IoT is its open source nature, which enables interoperability. A threat to this would result in upheaval of the entire industry, beyond just the dollars and cents in the tables above. As with any new and disruptive technology, first comes the innovation and then comes the regulation, whether from legislation, regulators, or the judiciary. A world of "walled gardens" in IoT would be a disaster for the industry and consumers alike, as it would increase costs for all concerned and make products less useful.

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<sup>26</sup> Grand View Research. 2017. Industrial Internet of Things (IIoT) Market Analysis.

<sup>27</sup> Accenture Technology. 2017. Winning with the Industrial Internet of Things.

<sup>28</sup> CB Insights. 2017. Industrial IoT Hits Another Annual High In Deals And Dollars.

<sup>29</sup> Gartner. 2017. Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016.

Several recent court cases show how attempts to lock-down and prevent interoperability by controlling APIs or similar concepts can impact or even curtail the growth of IoT:

- *Oracle v. Google*<sup>30</sup>

Oracle sued Google on various IP claims in 2010, shortly after it acquired Sun, which had created the (free and open) Java programming language. When Google created Android, it allowed developers to write code for Android using the Java programming language. Google used the same names and organization as the Java language APIs; which were essentially the interfaces by which software programs communicate and can be interoperable. Oracle alleged this reuse of names and organizational structure infringed its copyrights in Java.

In June 2012, the Northern District of California ruled that the elements of the Java APIs used by Google were not copyrightable. This was overturned by the U.S. Court of Appeals for the Federal Circuit in 2014, and returned to a jury trial the Northern District of California. The jury unanimously found that Google's use of the Java API was permissible as fair use under Section 107 of the U.S. Copyright Act. Oracle subsequently appealed that decision, which is still ongoing.

Were Oracle to win on appeal, it would be able to control the interoperability of third party software using the Java language and APIs. The negative impact of the precedent would be far broader than just how developers use Java. It could allow other platforms to lock down and prevent interoperability by controlling APIs in a similar fashion.

- *Cisco v. Arista*<sup>31</sup>

Arista, a manufacturer of high-end switching equipment, was sued by Cisco for using the same commands as Cisco's Command Line Interface (CLI). The jury ruled in Arista's favor, finding that CLI commands were unoriginal and the work can only be done in a limited number of ways, which covered Arista's use under the "scènes à faire" doctrine.<sup>32</sup>

Following the court decision, Arista was successful at invalidating several Cisco patent claims,<sup>33</sup> but Cisco successfully sued the United States International Trade Commission to bar the importation of Arista devices,<sup>34</sup> and a federal court upheld that exclusion order in November 2017.<sup>35</sup> The case is now on appeal.

- *GDC v. Dolby Laboratories*<sup>36</sup>

Dolby helped usher in the age of digital cinema, which requires media servers, sound, and

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<sup>30</sup> Electronic Frontier Foundation. 2017. Oracle v. Google

<sup>31</sup> Law360. 2014. Cisco Systems Inc-v-Arista Networks, Inc.

<sup>32</sup> Ars Technica. 2016. Arista beats Cisco's \$335M copyright claim with an unusual defense.

<sup>33</sup> Law360. 2017. Arista Invalidates Cisco Patent At PTAB, Vows ITC Action.

<sup>34</sup> CRN News. 2017. Cisco, Arista Trade Barbs After US Product Import Ban Upheld.

<sup>35</sup> Lexology. 2016. Federal Circuit Upholds ITC Exclusion Order.

<sup>36</sup> Law360. 2016. GDC Technologies Limited v. Dolby Laboratories, Inc.

projectors to show movies, plus the software that ties everything together. Dolby first encouraged others in the industry to use its code as standard, but it later introduced new products and claimed exclusive rights over the code it had developed and previously shared. GDC sued over this new claim, arguing that interoperability code (the language that allows different components to talk to one another) is not protected and is covered by fair use. The Hollywood Reporter referred to the case as deciding “the future of digital cinema.”<sup>37</sup>

The case was settled with licensing agreements part of the resolution, leaving the legal questions unsettled.<sup>38</sup>

- *SAS Institute v. World Programming*<sup>39</sup>

World Programming Limited created a platform on which people can run programs written in the SAS Language (which was created by the SAS Institute). SAS Institute sued WPL, arguing that WPL copied input and output formats and how a program interprets the SAS Language. However, WPL didn’t have access to the original source code. The EU Court of Justice ruled that copyright does not extend to software interfaces and programming languages.

### Impact on restricted interoperability in the industry

Throwing a wrench in the gears of interoperability will have numerous impacts on the economy and extend beyond the accounting outlined in previous sections in ways that are impossible to calculate. Over time, the fracturing that would occur in the IoT market could upend the entire IoT sector.

Beyond the launch of new products, the major way that innovation manifests itself in the IoT sector is through the development and spread of third-party application programming interfaces (APIs). Not only do APIs provide more flexibility and customization to developers and users alike, they also allow smaller companies to provide services or tools to their users that they otherwise couldn’t without huge support costs. There are thousands of APIs available today, and this is a huge growth market.

All of that would change if the IoT sector is fractured into different “walled gardens” defined by proprietary APIs that can only be used with permission. A game-changing API would be capped at a small fraction of the overall market. Even if that API could be re-implemented in different languages (uncertain with the type of changes to interoperability that could occur), it would take significantly more time and effort not only to make the API available in other languages but also to provide continual support.

There are myriad consequences to this, and none of them are good. A fractured market would lock consumers into one narrow suite of products that use a common set of APIs. Other new products, regardless of quality or function, would be incompatible with existing products, forcing consumers into a choice: pay heavily to replace their current products, or settle for an

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<sup>37</sup> Hollywood Reporter. 2016. The Future of Digital Cinema May Be At Stake in Lawsuit Over Interoperability.

<sup>38</sup> Film Journal International. 2016. GDC and Dolby resolve litigation.

<sup>39</sup> EU Court of Justice. 2012. Judgment of the Court, C-406/10.

inferior or less desirable product. Limited options means limited choice and competition, which reduces the quality of products.

It also reduces the incentive to innovate or improve product offerings. For larger businesses that create IoT products, the lack of competition means they can save on the cost to offer better or more secure updates. The consequence for smaller businesses is even more dire, as the potential market share for their product may be too small to consider starting in the first place. Even if they decide to start-up, the uncertainty and narrowness of the market would make it exceedingly difficult to find investors.

Finally, the companies that control proprietary APIs essentially become gatekeepers – or fiefs. The ability to make exclusive and license technology would give tremendous power to those owners and create an environment where only larger, more established businesses can operate, and further reducing the ability of start-ups and small businesses to compete.

All of these effects have a common theme: increasing the gap between the biggest players and small businesses. We see around the U.S. the increasingly consolidated nature of the largest businesses, which can stifle small businesses and would-be competitors. Technology has always been more prone to disruption, where two guys in their garage still have the power to change the world. Upheaval to interoperability would make it less likely that those two guys even try.

### Increased security risks

Beyond the financial impact, there are the very real security risks that will come as a result of a fractured market. Security in tech is often the result of consensus and best practices, which tend to be adopted over time across platforms or operating systems. In a fractured market, with barriers between different types of IoT devices, the penetration rate of the best devices slows down, leaving more devices more vulnerable for longer.

More devastating is the lack of innovation that is often responsible for leaps in security. Innovation can occur when someone has a burst of inspiration, or stumbled upon unintentionally. The best environment for innovation is with a multitude of people involved, with multiple opportunities to find their bursts of inspiration, or discover a problem that results in a groundbreaking security solution. A fractured market, especially one that leaves more power and resources consolidated in larger companies who don't have to take risks, dramatically limits the opportunity for these discoveries and slows the pace of security advances.

Security risks in IoT go far beyond money or even personal data (though the risk of the latter can be extreme). With interconnected devices in houses, cars, workplaces, and pockets or wrists, the vulnerabilities extend to the physical, tangible day-to-day life, and can even put lives at risk.

### Impact on developer workforce

The most recent estimate of software developers is over 21 million people globally.<sup>40</sup> Prior research has estimated that developers include two major subcategories: professionals (59.5%) and hobbyists (40.5%).<sup>41</sup> We estimate there are 4.2 million developers in the U.S., accounting for

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<sup>40</sup> Evans Data Corporation. 2017. Global Developer Population and Demographic Study 2017 Vol. 1.

<sup>41</sup> IDC. 2014. Global Software Developers.

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.

Table 5.  
US Employers Look to Hire Developers Who Are Familiar with Several Programming Languages<sup>42</sup>

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. This demand is used to estimate the number of developers that use the Java programming language. We estimate approximately 1.6 million software developers in the U.S. and 8.8 million software developers globally use the Java programming language.

Table 6.  
US Developers that Use Java<sup>43</sup>

	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

<sup>42</sup> ndp | analytics analysis of Indeed.com data.

<sup>43</sup> BLS. 2016. Occupational Employment Statistics; ndp | analytics analysis of Indeed.com job postings.

Notably, the Java programming language is even more common for developers working on IoT and open source projects. A recent survey found that, in 2017, 61% of developers use the Java programming language to build IoT solutions, up from 52% in 2016.<sup>44</sup> 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 repository, second only to JavaScript.<sup>45</sup> As a result, it is expected that a large share of IoT software can be traced back to open source programs written using Java.

In a fractured market, most of those developers would have to learn new languages or new API commands just to keep their jobs. These are no small challenges. The best programmers have years of experience in their respective languages. The amount of time and investment spent to become the top Java programmers will no longer be a valuable, transferable skill to future employers, which limits their prospects and puts additional costs and strain on developers.

Interoperability goes a long way to mitigate that, so much so that one of the most promising developments of the past few years was designed with the explicit goal addressing this issue. Microsoft launched an open-source initiative called Bridge to help bring Android and iOS skill-sets for use on WinMobile devices. After months of work and contributions, the project became unwieldy and they made the decision to focus solely on iOS.<sup>46</sup> This illustrates the gap between products running on different languages, and the difficulty in switching from one to another. In short, dismantling interoperability bankrupts the value of the skills millions of developers in the workforce today.

For the same reason, it also increases the risk for companies to hire developers, as the decision of which language to use for a new suite of products would mean a smaller pool of qualified developers from which to choose. They also stand to lose out on the best developer fits in order to satisfy the technical demand of the new onerous restrictions placed upon them.

Whether it's the diminished value of a skillset or the additional difficulty of finding a job, the results are greatly increased barriers of entry for new and old developers alike. Every new barrier to entry represents diminished growth, reduced innovation, fewer jobs, and less economic productivity.

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<sup>44</sup> Eclipse et al. 2017. IoT Developer Survey.

<sup>45</sup> <https://octoverse.github.com/>

<sup>46</sup> Windows Blog. 2016. An Update on the Developer Opportunity and Windows 10.

## Conclusion

The key to unlocking the tremendous potential of IoT lies in interoperability. Open source software is the common toolset that enables thousands of developers to independently build complex and interacting systems, knowing that their work will mesh seamlessly with that of their peers.

Threats to interoperability, whether from policy, regulation, or a court decision, would have a shockwave effect on the entire technology sector. The ones bearing the brunt of that impact would be the developer workforce. We cannot overstate the importance of open source and interoperability. It's not merely about developer careers and paychecks; open source projects are where ideas are born, finessed, debugged, shared, and launched. Open source is what makes the IoT work.

The threat to companies that hire developers is also severe, particularly those in the IoT sector. Beyond the impact on the developers they hire are the security risks, now multiplied, that they must overcome. The capital outlay for more specialized developers to handle the upheaval would impair growth and set the entire industry back. It may even discourage some companies from starting at all, or scare away investors who give them the runway needed to launch. The result would be a serious imbalance where only the biggest companies have the resources to compete, further stifling innovation.

While the impact of what's described above is incalculable and has far-reaching, trickle-down implications, there are real dollar figures attached to the prospect of shaking the foundation of IoT by disrupting interoperability. Looking solely at Home IoT and Auto IoT, we estimate that **\$77 billion** is directly attributable to the open source nature of IoT products and services and is at risk over the next eight years.

That figure, in addition to other sectors like Industrial IoT, and the impact on developers, underscores the severity of the threat. Interoperability is imperative to the future of the developer workforce. Any threat to interoperability is a threat to developers, to tech companies, and to the billions of dollars in economic productivity they produce.



## References

- AAA. 2016. American Driving Survey 2014-15. <https://www.aaafoundation.org/sites/default/files/AmericanDrivingSurvey2015.pdf>
- Accenture Technology. 2017. Winning with the Industrial Internet of Things. <https://www.accenture.com/us-en/insight-industrial-internet-of-things>
- 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. <http://airccse.org/journal/ijsea/papers/0111ijsea01.pdf>
- Ars Technica. 2016. Arista beats Cisco's \$335M copyright claim with an unusual defense. <https://arstechnica.com/tech-policy/2016/12/jury-clears-arista-of-ciscos-335m-copyright-claim/>
- BI Intelligence. 2016. Automotive Industry Trends: IoT Connected Smart Cars & Vehicles. <http://www.businessinsider.com/internet-of-things-connected-smart-cars-2016-10>
- Bureau of Labor Statistics. 2017. American Time Use Survey, 2016. <https://www.bls.gov/tus/>
- Bureau of Labor Statistics. 2016. Occupational Employment Statistics. <https://www.bls.gov/oes/>
- CB Insights. 2015. Reinventing The Wheel: 41 Auto Tech Startups Disrupting The Car Industry. <https://www.cbinsights.com/research/auto-tech-startups/>
- CB Insights. 2017. Industrial IoT Hits Another Annual High In Deals And Dollars. <https://www.cbinsights.com/research/industrial-iot-startup-funding/>
- CB Insights. 2017. Smart Home Market Map: 60 Startups In Home Automation, Smart Appliances, And More. June 26. <https://www.cbinsights.com/research/smart-home-market-map-company-list>
- comScore. 2017. U.S. Smartphone Penetration Surpassed 80 Percent in 2016. <https://www.comscore.com/Insights/Blog/US-Smartphone-Penetration-Surpassed-80-Percent-in-2016>
- CRN News. 2017. Cisco, Arista Trade Barbs After US Product Import Ban Upheld. <http://www.crn.com/news/networking/300089196/cisco-arista-trade-barbs-after-us-product-import-ban-upheld.htm>
- Crunchbase. 2017. Company database. <https://www.crunchbase.com/#/home/index>
- Eclipse et al. 2016. IoT Developer Survey. <https://www.slideshare.net/lanSkerrett/iot-developer-survey-2016>
- Electronic Frontier Foundation. 2017. Oracle v. Google. <https://www.eff.org/cases/oracle-v-google>
- EU Court of Justice. 2012. Judgement of the Court, C-406/10. <http://curia.europa.eu/juris/document/document.jsf?docid=122362&doclang=EN>

Evans Data Corporation. 2017. Global Developer Population and Demographic Study 2017 Vol. 1. <https://evansdata.com/reports/viewRelease.php?reportID=9>

Film Journal International. 2016. GDC and Dolby resolve litigation. <http://www.filmjournal.com/news/gdc-and-dolby-resolve-litigation>

Forbes. 2015. Connected Cars. [https://blogs-images.forbes.com/niallmccarthy/files/2015/01/connected\\_cars\\_forbes.jpg](https://blogs-images.forbes.com/niallmccarthy/files/2015/01/connected_cars_forbes.jpg)

Gartner. 2017. Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016. <https://www.gartner.com/newsroom/id/3598917>

Grand View Research. 2017. Industrial Internet of Things (IIoT) Market Analysis. <http://www.grandviewresearch.com/industry-analysis/industrial-internet-of-things-iiot-market>

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>

Hollywood Reporter. 2016. The Future of Digital Cinema May Be At Stake in Lawsuit Over Interoperability. <https://www.hollywoodreporter.com/thr-esq/future-digital-cinema-may-be-882944>

IDC. 2014. Global Software Developers Business Wire. 2017. "Global \$34.52 Billion Smart Appliances Market 2017 - Forecasts from 2016 to 2021 with General Electric, LG Electronics, Panasonic, Samsung, and Whirlpool Dominating - Research and Markets." Business Wire. March 9. <http://www.businesswire.com/news/home/20170309006267/en/Global-34.52-Billion-Smart-Appliances-Market-2017>

IHS Markit. 2016. Automotive Industry Outlook: Navigating the Waters in a Post-Recovery Environment. [https://www.spratings.com/documents/20184/908551/US\\_CO\\_Event\\_Auto2016\\_Article3.pdf/21ebbbdb-40fb-4f9c-949e-136af209f63f](https://www.spratings.com/documents/20184/908551/US_CO_Event_Auto2016_Article3.pdf/21ebbbdb-40fb-4f9c-949e-136af209f63f)

International Monetary Fund. 2017. FAQ: WEO Country Groups and Purchasing Power Parity (PPP). <https://www.imf.org/external/pubs/ft/weo/faq.htm#q4b>

Law360. 2014. Cisco Systems Inc-v-Arista Networks, Inc. <https://www.law360.com/cases/5481cf5f3bcd57b5000002>

Law360. 2016. GDC Technologies Limited v. Dolby Laboratories, Inc. <https://www.law360.com/cases/570bed23f7526163bb000004>

Law360. 2017. Arista Invalidates Cisco Patent At PTAB, Vows ITC Action. <https://www.law360.com/articles/930665/arista-invalidates-cisco-patent-at-ptab-vows-itc-action>

Lexology. 2016. Federal Circuit Upholds ITC Exclusion Order. <https://www.lexology.com/library/detail.aspx?g=41d44b43-35ec-43d9-91de-d5881a9f155c>

McKinsey Global Institute. 2015. The Internet of Things. Mapping the Value beyond the Hype. <https://www.mckinsey.com/~media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/The%20Internet%20of%20Things%20The%20value%20of%20digitizing%20the%20physical%20world/The-Internet-of-things-Mapping-the-value-beyond-the-hype.ashx>

PwC. 2017. Smart home, seamless life. <https://www.pwc.com/us/en/advisory-services/publications/consumer-intelligence-series/smarthome.html>

Quartz. 2017. Coming Soon: The Internet of Clothes. <https://qz.com/664059/coming-soon-the-internet-of-clothes/>

Riehle, Dirk. 2015. How Open Source Is Changing the Software Developer's Career. IEEE <http://ieeexplore.ieee.org/document/7111876>

Postscapes. 2017. Home IoT Guide. <https://www.postscapes.com/internet-of-things-award/connected-home-products/>

Spoke Intelligence and Readwrite. 2017. The IoT Revolution Landscape. <https://drive.google.com/file/d/0B2gl-SP5WmzMVcxVFZDTnlCX3c/view?submission=293902691>

Statista. 2017. Connected Car Market, United States. <https://www.statista.com/outlook/320/109/connected-car/united-states#>

Statista. 2017. Smart Home Market, United States. <https://www.statista.com/outlook/279/109/smart-home/united-states>

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/>

Texas A&M. 2015. National Congestion Tables and Trends, 2014. <https://mobility.tamu.edu/ums/national-congestion-tables/>

U.S. Department of Transportation National Highway Traffic Safety Administration. 2015. Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115>

Windows Blog. 2016. An Update on the Developer Opportunity and Windows 10. <https://blogs.windows.com/buildingapps/2016/02/25/an-update-on-the-developer-opportunity-and-windows-10>

World Bank. 2017. Global Economic Prospects. <http://www.worldbank.org/en/publication/global-economic-prospects>



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