Fog Computing

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Abstract

During my studies here at East Carolina University, I have studied and read about many different t types of emerging technologies. For this writing, I will be focusing on fog computing. Before this report, I had only heard of fog computing mentioned occasionally during various courses. I never really focused in depth on what fog computing is, where the concept of fog computing came from, how it came about, why it has been introduced, and how fog computing will shape the future of information technology. With this writing, my goal is to address every point mentioned above, and provide in depth knowledge of real world cases and examples of how and where fog computing is currently being used today. I will also discuss how fog computing coincides with other forms of emerging technology, and will try to gauge what impacts that these technologies will have on the future of information technology.

Introduction to fog computing

What exactly is fog computing? Fog computing can be defined as a decentralized computing infrastructure where computing resources and application services are distributed logically from the data source to the cloud. So what does this really mean? In order to help our readers better understand this, please refer to **Figure 1.1 (**Foggy about 'Fog Computing'"?).

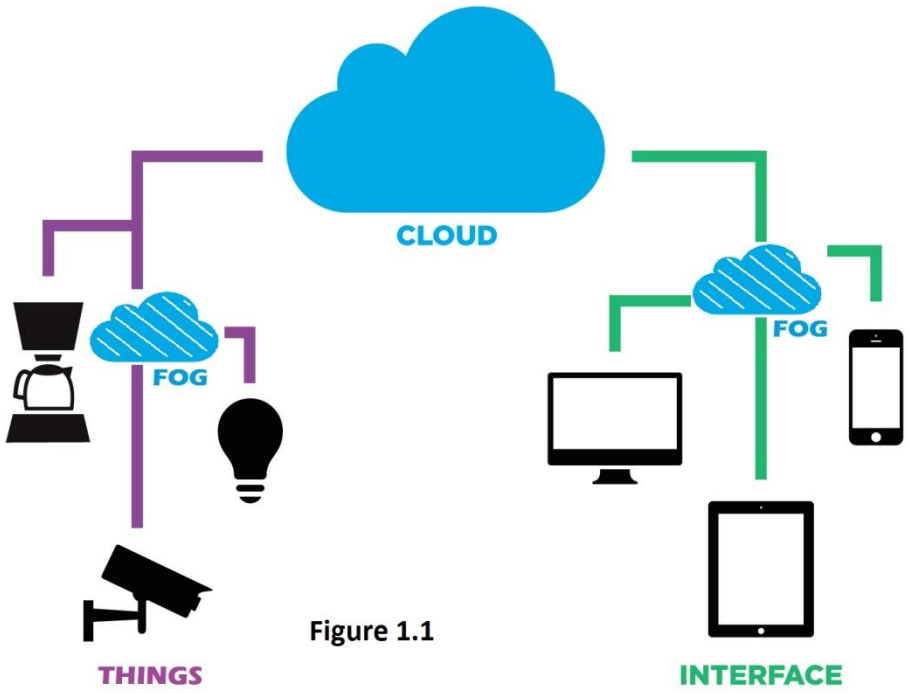

Figure 1.1

The "fog" essentially acts as an intermediary between endpoint clients and cloud computing. Fog computing occurs near the edge of the cloud, and the end of endpoint devices, so many refer to fog computing as "edge computing". Information moves from endpoint devices such as smart phones, computers tablets, sensors, actuators, programmable logic controllers (which are used in manufacturing facilities with automation), routers, hubs, and other IP address driven things to the fog, and then to the cloud. Essentially anything that can communicate over a network can be an

end point device. In many information technology expert's eyes, fog computing may be the answer to a lot of problems that have risen from the rise of the Internet of Things. Now that we have a little bit of information about where fog computing takes place, we can move on to more details about why fog computing was created. Fog computing is a direct result of the Internet of Things. We will discuss the Internet of Things and it's affects of fog computing in the next section of this document.

The rise of the Internet of Things

Worldwide, humans transfer massive amounts of data each and every day. Some of us have multiple cell phone devices, many different laptops, smart cars, and many other wireless devices that utilize the internet to transmit data from one place to another. The need for so many devices has grown exponentially over the past decade and is not showing any indication of this growth to slow down. The Internet of Things refers to the massive amount of devices that connect to the internet in order to send and receive information and data. **Figure 1.2** helps show

readers how much growth there has been in the past few decades.

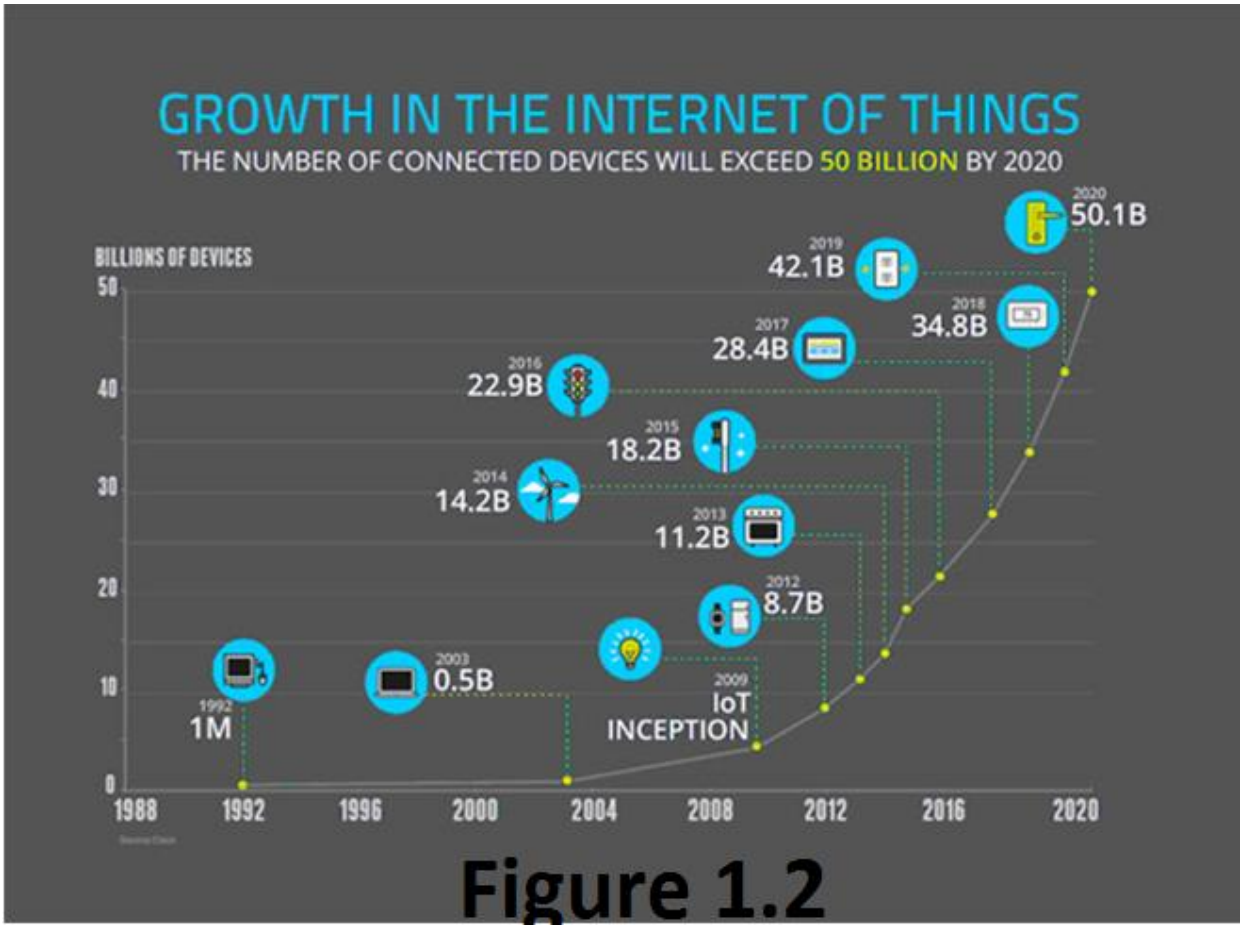

Figure 1.2

During 2004, only an estimated half a billion devices needed to connect to the internet to move data. Fast forward to today, in 2016, that number has exponentially grown to an estimated 22.9 billion devices that connect to the internet. Many of these devices that are connecting to the internet send and store information on the cloud. Companies such as Google, Dropbox, Apple, and Verizon have storage servers on clouds that allow for clients to transmit data to the cloud in the form of backups, and retrieve that data if needed. Physically, these servers can be very long distances away. The longer the distance, the longer it takes for data to be moved from one place to the other due to latency. Also, the longer the distance, the more time is available for an attacker to attempt to strike. If we look at Figure 1.2 again, we can see that in the next four

years, the amount of devices are expected to literally double to over fifty billion devices. How will our current cloud infrastructure be able to handle all of these devices? The more devices that are connected in the Internet of Things, the more of a burden they are within the cloud. More devices equals congestion and overload of the cloud, cloud servers, and cloud services. The more and more that we as humans depend on technology, the more impact that this will have on cloud computing. The implementation of fog computing will overall benefit cloud computing, as well as deliver a better end user experience (***"Ijret: International Journal Of Research In Engineering And Technology"). We will discuss how fog computing can help alleviate the issues that the Internet of Things are facing today in the next section of this writing.

Functions of fog computing

As mentioned in previous sections, the cloud is becoming congested with more and more devices that are connecting to the internet. These devices transmit and receive data to the cloud. What does fog computing do in order to help alleviate the issues that cloud computing is experiencing due to the Internet of Things? Fog computing utilizes fog nodes that are located on the edge of networks, or in the fog. Fog nodes are typically storage devices that are located in between users and the cloud. Essentially, fog nodes are storage servers that are located closer to end users. Due to the decreased distance between end user devices and fog nodes, end users benefit due to decreased latency in data transmission and retrieval. Owners of fog nodes can use them as local cache storage nodes to help better serve clients by storing frequently accessed data closer to the client instead of on a cloud based server. Data that is not accessed frequently may be placed on the cloud based server, and retrieved upon client request.

Cloud computing vs fog computing

To begin this section, we must realize that fog computing is not here to replace cloud computing. These two technologies are different, yet similar in ways. The biggest similarity between these two are the fact that they typically act as storage devices for end point users and devices. This table highlights the main differences between cloud computing and fog computing at various levels.

Requirements	Cloud Computing	Fog Computing
Latency	High	Low
Delay Jitter	High	Very low
Location of Service	Within the Internet	At the edge of the local network
Distance between client and server	Multiple hops	One hope
Security	Undefined	Can be defined
Attack on data enroute	High probability	Very low probability
Location awareness	No	Yes
Geo-distribution	Centralized	Distributed
No. of server nodes	Few	Very large
Support for Mobility	Limited	Supported
Real time interactions	Supported	Supported
Type of last mile connectivity	Leased Line	Wireless

One of the largest differences between these two is latency. Latency is the amount of time or lag that it takes for a local user to send, receive, or retrieve data from a cloud based server or using cloud services. With cloud computing, latency can be high, due to the large amount of other devices that can possibly be accessing that server for data. Fog computing combats latency, mainly in part because fog nodes are physically located much closer to clients. Fog nodes are geographically distributed, so data from sensors, probes, and other end user devices have much less latency than cloud based computing due to less distance for information to have to travel for

storage(***"Yi, Shanhe, Cheng Li, and Qun Li"). Endpoint clients benefit greatly with the use fog computing for this very reason, fast data retrieval. Fog computing is considered by some Information security experts to be much more secure than cloud computing in that due to information not having to travel great distances experienced by cloud computing. Reaction times would be much faster because of the end user's distance in relation to the fog nodes. Also, fog nodes would enable much faster data breach notifications as far as local clients are concerned because data can be accessed faster given that it is only one network hop away instead of multiple hops away in a cloud computing environment. Although this has been quietly mentioned above, the biggest difference between cloud computing and fog computing is the fact that cloud computing is more centralized, and fog computing is more geographically distributed, which as we just mentioned helps benefit the end user client by lower latency and faster data transmission ("Welcome to the Fog – A New Type of Distributed Computing.").

Advantages

Although we have touched base on a lot of these advantages earlier in this writing, we can discuss in detail of the advantages of the implementation of fog computing and the positive impacts on the Internet of Things issues that we are facing today. We know from the previous section that fog computing uses fog nodes that are more geographically distributed and much closer to the client, which results in faster data retrieval times. This ultimately results in a much more positive end user outcome ("Fog Computing, the Cloud Computing of the IoT"). Fog nodes can be managed by administrators, typically by companies that implemented them. They are typically used by companies that have large client bases that rely on data backup and retrieval, such as iCloud services via Apple, or Vcloud via Verizon, and even Microsoft

OneDrive. All of these services are essentially the same. They store user data on the server, and anytime the user needs this data, they can contact the server and retrieve any data that they want. Servers may be multiple router hops away, resulting in slow and laggy data retrieval. If these companies deploy fog nodes, which some already do, then their users and customers may access stored data and information on those fog nodes instead of having to resort back to the cloud based server storage. Fog nodes can actually be managed to be local cache storage in between the cloud and the end point device. With that being said, the company that implements fog nodes can use statistical analysis to decide what data is constantly being used, and what data is rarely, if ever used. Regardless of how often this data is being used, if the user needs that data five years later, they will want to make sure they can still have access to this data. Companies can manage what client data they would like to store on the cloud, and what information and data they would like to store on the storage nodes located in the fog. To cut down on the need for users to access data on cloud servers that can be extremely far away, which would use a lot of bandwidth on cloud servers and services, they can store frequently used data on fog nodes, and rarely ever used data on the cloud servers. This helps lessen the burden of users accessing the cloud, while it increases the user's speed of transmitting data, further resulting in positive results on the client end.

Disadvantages

Based on the information provided, one may think that fog computing is the answer to the entire Internet of Things issue. Although there are a lot of advantages, there are also some disadvantages that must be addressed. One of the largest drawbacks to fog computing is the fact that it is not a very old concept. This concept emerged as a direct result of the anticipated issue

of the Internet of Things and the exponentially increasing amount of devices being used today. Not a lot of people are even aware of fog computing, much less the benefits that may come along with it. I did not have much in-depth knowledge of fog computing before researched this topic very thoroughly. In the previous section, security was listed as an advantage due to less time for information to travel, thus resulting in less time to be intercepted by an attacker. Security can also be listed as a disadvantage due to the fact that fog computing is such a young concept. Fog computing and fog nodes are a new technology, which means that they may not have a widely used infrastructure yet. As we know, attackers typically go after widely used platforms, for example Microsoft has a commanding market share on personal computer devices. It is no surprise that it is the most commonly attacked operating system. As fog computing continues to grow, more and more security concerns may come about. Since fog computing uses fog nodes to transmit confidential end user data, what exactly does the device and fog node use to encrypt data being transmitted? Are there encryption keys used? Certificates? The answer is certificates embedded in the data help ensure that data that comes from one device communicates with a legitimate fog node. With these matching certificates on both ends, data is securely transmitted from the end user device to fog nodes located in the fog. Lastly, cost of implementation is another issue. The client should not have any direct costs of using or accessing fog nodes to transmit data and using a fog computing based infrastructure. Costs actually come from the corporations such as Verizon, Apple, Google, Amazon, and Dropbox that have clients that are directly impacted by the movement of their data. Obviously companies want to have a competitive edge, and that competitive edge could very well be faster data retrieval for their clients. These companies are pushing for fog computing technology in order to give their organization an edge versus other competitors in the market, thus cost falls on these companies.

Whether or not the costs will eventually trickle down to the consumer is hard to say at this point, but it very well could. Clients may eventually see this trickle down affect as fog computing is implemented by data centers and other intermediary cloud services.

Current implementations and examples

For this section, we will discuss some current implementations and examples of how fog computing is starting to gain traction as a viable source of supplementation to cloud computing. Cisco has spearheaded fog computing because they it being a major dependence on the movement of data in the future. Cisco feel that fog computing can be the answer to the issues we will soon be facing with the Internet of Things. Although fog computing will never replace cloud computing, it would be a great supplement to cloud computing, as we have discussed in previous sections. Cisco currently implements fog nodes and fog computing by supporting wireless data transfers that communicate to distributed devices within the Internet of Things. Cisco is devoted to bringing data closer to the end user, which is exactly what fog computing does by using geographically distributed fog nodes as storage devices located within the fog ("Ubiquity: Fog Computing Distributing Data and Intelligence for Resiliency and Scale Necessary for IoT"). Many internet service providers provide email services to their clients. Some of these providers use email servers that are located in the cloud. Clients that use email provided by these internet service providers frequently place local caches of emails on fog nodes. As we have discussed in previous sections, when data is located on fog nodes, data retrieval is much faster than if it were on cloud based servers. Another example of fog computing would be cell phone towers. Just about everyone has access to a cell phone, or multiple cell phones for work and personal use. That being said, people transfer and receive a lot of data. Sensors and

actuators will be a huge market for fog computing because it can transmit data to companies very quickly due to fog nodes being close to the end user. If there is a large sporting event and tens of thousands of devices are overloading a particular cell phone tower, the cell phone provider will actually be able to direct new traffic to surrounding towers to help alleviate issues with the overloaded tower based on a sensor that was uploading real time data to fog nodes. Fog computing is real, and based on the ability to ensure a better end user client user experience, it is here to stay.

Future/Conclusion

The future of fog computing is just like any other emerging technology, it can change very rapidly, depending on what needs arise and changing needs. As we have discussed throughout this entire document, the Internet of Things will only continue to grow exponentially. More and more devices will continue to connect to internet based storage and will need to be able to communicate and send and receive data to various cloud based servers and fog nodes. Smart cars, military weapons, smart homes, and cellular devices will continue to add to the burden that the Internet of Things has created. Based on this, fog computing will only become more and more relevant. More technologies will come about that will help combat the issues faced with the Internet of Things, and fog computing may possibly evolve and adapt to other needs. Although fog computing may be just one alternative to alleviate or supplement cloud computing, it will never replace it. Before fog computing can become a more accepted and larger concept, there will need to be more innovation and research conducted, as well as more client and corporate knowledge of the possible benefits that fog computing can possibly deliver.

Companies such as Cisco will continue to be on the forefront of the development and implementation of fog computing (*** "Cloud Computing - Case Studies.").

Bibliography

"From Cloud to 'Fog' Computing: Cisco Looks to Accelerate IoT Innovation." *L'Atelier : Accelerating Innovation*. N.p., n.d. Web. 27 June 2016.

"Blogs." *Cloud Backup Solution from the Cloud Backup Experts*. N.p., n.d. Web. 28 June 2016.

"New Fog Computing To Out Smart Cloud Computing." *IndianWeb2com*. N.p., 09 Dec. 2014. Web. 28 June 2016.

IoT, from Cloud to Fog Computing." *Cisco Blog RSS*. N.p., n.d. Web. 27 June 2016.

"Foggy about “Fog Computing”?" *IoT Labs*. N.p., n.d. Web. 14 July 2016.

*** Yi, Shanhe, Cheng Li, and Qun Li. "A Survey of Fog Computing." *Proceedings of the 2015 Workshop on Mobile Big Data - Mobidata '15* (2015): n. pag. Web.

"Fog Computing: A New IoT Architecture? - RTInsights." *RTInsights*. N.p., 21 Mar. 2016. Web. 12 July 2016.

*** Ijret: International Journal Of Research In Engineering And Technology, and Eissn: 2319-1163 | Pissn: 2321-7308. *REVIEW OF IMPLEMENTING FOG COMPUTING* (n.d.): n. pag. Web. 8 July 2016.

"Fog Computing, the Cloud Computing of the IoT." *Welcome to The IoT World of Telefónica*. N.p., n.d. Web. 8 July 2016.

"What Is Fog Computing?" *HowTo Geek RSS*. N.p., n.d. Web. 1 July 2016.

*** "Cloud Computing - Case Studies." *Cisco*. N.p., n.d. Web. 9 July 2016.

"Welcome to the Fog – A New Type of Distributed Computing." *Data Center Knowledge*. N.p., 23 Aug. 2013. Web. 1 July 2016.

"Ubiquity: Fog Computing Distributing Data and Intelligence for Resiliency and Scale Necessary for IoT." *Fog Computing Distributing Data and Intelligence for Resiliency and Scale Necessary for IoT*. N.p., n.d. Web. 5 July 2016.