As part of Internet.org’s mission to bring affordable internet access to the two-thirds of the world not yet connected, Facebook and Ericsson, in conjunction with XL Axiata, created a new methodology to measure and improve end-to-end network performance using Facebook application use cases. Previously, networks have been tuned to improve voice services using traditional network KPIs, and for large video/data downloads. This approach does not address mobile application performance, as the data and network signaling needs are different. Ericsson and Facebook were able to correlate user-centric KPIs from the Facebook application with network KPIs to show the links between user experience and network performance.
The rise of data traffic in mobile networks has been rapid and overwhelming. Data surpassed voice traffic globally in 2009 and is now more than 10 times greater, while the mass adoption of smartphones and the data-centric applications that run on them has sparked a revolution in user behavior and expectations, not to mention the transformation of entire industries.

Today’s users want their apps to work anywhere, anytime and at top speed, and this means that network performance in terms of data – what we call app coverage – has never been more important. Simply put, app coverage looks at the network from a user perspective and allows operators to evaluate whether a user will be satisfied with their experience of a specific app in a given location at a given time. App coverage brings together all aspects of network performance – such as radio network throughput (see Figure 1), latency and capacity, as well as the performance of the backhaul, packet core and content delivery networks (CDNs), and performance variations between high- and low-end devices.

Ultimately, app coverage can be used as one way to judge the performance of a mobile operator’s network. App coverage – or a lack of it – also impacts how users evaluate individual apps and shapes the ability of app developers to provide a high-quality user experience. Conversely, the way that developers design apps to relate to the network is also a key consideration in optimizing the mobile user experience.

So, the app coverage approach is important for users, developers and operators alike. But it turns out that it is not easy to measure quality of experience (QoE) for users within data-centric applications. And if you can't measure it, how do you improve it?

With this in mind, Facebook and Ericsson, together with XL Axiata, engaged in a joint project in the first half of 2014 to monitor, analyze and improve the user experience of Facebook – one of the world’s most widely used mobile apps – in a live environment in XL Axiata’s network in Indonesia.

Ericsson developed a series of metrics on end-to-end network experience as it impacts app coverage. Then, using a test agent developed by Facebook, typical Facebook interactions were triggered and measured on different mobile devices in urban, suburban and rural regions across the XL Axiata coverage area.

At the same time, Ericsson and XL Axiata collected network metrics in the areas where the test agents were deployed. Using this data, engineers correlated both the network data and the end-to-end metrics and were able to develop a methodology to identify bottlenecks in the network performance from the user perspective. The figure below illustrates how app coverage can be impacted by radio network throughput variances within a cell site.
end-to-end setup. This resulted in substantial improvements in the radio access network (RAN), the core network and the CDN. Results showed app coverage improvements of 20 to 70 percent, defined as the number of transactions that finished within three seconds. Within that scope, time to content improved up to 70 percent, while upload time improved up to 50 percent.

The results show that it is possible to increase app coverage using existing network resources. This has the potential to benefit existing users globally and is also key to helping the next 4 billion internet users get online – especially in rural areas with little to no data coverage – allowing them to reap the benefits of a connected world: what we call the Networked Society.
How to measure app coverage

In advanced mobile markets, data traffic has long replaced voice and SMS as the primary driver of network traffic. In Q1, 2014, mobile data traffic exceeded the total mobile data traffic for the whole of 2011, and by 2019, data traffic is now projected to grow more than tenfold from its current level [1].

Apps, smart devices and mobile networks – as well as the companies and developers that make them – together form a single ecosystem that drives most of this growth (see Figure 2) [2]. Within this ecosystem, apps and smart devices are continuously evolving and being upgraded, and this places high demands on operator networks in terms of both network coverage and network load. At the same time, each specific app puts its own requirements on the network, including data requirements, its optimization level and impacts from its data fetch strategy. Taken together, this necessitates an end-to-end network view, as traditional network statistics alone may not reflect the actual user experience.

For operators, app coverage – which can be defined as the area within a mobile network’s coverage area that can deliver sufficient performance to run an application at an acceptable quality level – influences everything from brand reputation and customer loyalty to the ability to generate a sufficient return on investment. Expanding app coverage is also central to helping billions of people get connected to the internet for the first time.

Social media apps generally require a low data throughput despite the fact that people spend significant time with social media apps. In the US, for instance, Nielsen found in December, 2013 that users spent 29 percent of their mobile app time on social media [3].

However, while people love their apps, the apps often don’t work well. Smartphone users commonly report slow browsing and content download speeds, as well as a lack of internet coverage and a high rate of app crashes. In an Ericsson ConsumerLab study, 15-20 percent of respondents said they experience trouble with apps very often, and a further 45-50 percent said they experience them on occasion [4]. These complaints can have substantial consequences: A 2012 study from the University of Massachusetts Amherst, in the US, and Akamai Technologies found that internet users start abandoning attempts to view online videos if they do not load properly within two seconds. As time goes on, the rate at which viewers give up on a given video increases [5].

This is a particular issue in many Southeast Asian markets, including Indonesia, where an influx of cheaper smartphones – increasingly costing less than USD 100 – has given people by the millions the chance to join social media networks. Mobile data traffic for the region is projected to grow by more than 10 times between 2013 and 2019, reaching 2 exabytes by 2019 [6]. In a new report, McKinsey has also identified Indonesia as a market well positioned for fast mobile internet growth due to a relatively young, literate and well-off population [7], and the country already has the fourth-largest Facebook user base in the world.

Figure 2: The smart device ecosystem is interdependent and constantly evolving.
The Indonesian operator XL Axiata provides a good example of changing market and network realities. In 2013, its data revenue grew by 16 percent with data traffic rising by 142 percent. Of the company’s 62.9 million subscribers, more than half of the total base is made up of data users, with a majority of those using Facebook, according to XL Axiata estimates. XL Axiata also launched business collaborations with several social media and chat applications in 2013, including Facebook, in order to strengthen its position as a market leader in mobile data [8].

But transmitting data requires bandwidth, which can be scarce in many parts of the world. In its report, McKinsey identified infrastructure – including “underdeveloped national core network, backhaul, and access infrastructure” – as one of the four primary global barriers to connection [7]. For example, in Indonesia as a whole, 75 percent of users are on older 2G, or GSM/EDGE, networks [6], and the nation’s geography (it is made up of thousands of islands) presents additional challenges. In the ConsumerLab study, more than half of Indonesian smartphone users said they experienced network problems daily [4]. This can test application developers like Facebook, given that they often provide a visually oriented experience with constantly updated content and large-scale photos.

But while there is a clear need for widespread app coverage, today’s measurement tools provide relatively poor visibility of the true user QoE. For voice and SMS services, there have long existed well-known, static network KPIs, but these do not exist yet for packet data, which can’t be effectively measured using the voice-related KPIs. Within a network, a data packet doesn’t act like a voice call, which disappears if dropped. Instead, a packet – which can come from a variety of far-flung sources – remains present even if slowed by a bottleneck.

Data in a mobile network also originates from a wide spectrum of fast-evolving apps, both local and global, and this requires operators to make continuously updated decisions about service levels. On the other end, app developers face a similar uncertainty, as they must design their applications with myriad devices, platforms and network types – as well as performance levels – in mind.

Specifically, some of the limitations impacting the ability of operators and app developers to actively measure user QoE include:

- the scarcity of samples in both space and time
- results bias depending on when, where and how an app is used
- the difficulty of emulating over-the-top apps and associated content.

Both independently and as members of the Internet.org organization, Facebook and Ericsson have made it a priority to help operators tune and optimize their networks for better app coverage and more efficient data delivery, as well as to provide scaled-down apps that work well in network-constrained and price-sensitive environments. Examples of their common efforts include the founding of Internet.org, with other partners, in 2013, and a related Innovation Lab, scheduled to open in 2014, as well as a series of hackathons aimed at improving app performance in network conditions found in many emerging markets [9] [10] [11].

But only so much can be achieved under laboratory conditions. Measuring app coverage effectively requires seeing how apps work on real devices in real networks in a variety of real-time conditions. It was with this in mind that Facebook, XL Axiata and Ericsson agreed on a joint project to provide visibility of both the real user QoE across the mobile subscriber base, as well as any associated network limitations wherever and whenever these occurred.
In this section, we will provide an overview of the objectives, methodologies, tests, measurements and resultant improvements and optimizations that were undertaken to better understand and ultimately improve the Facebook experience in XL Axiata’s live commercial network. Within the scope of the project, Ericsson and Facebook also aimed to develop efficient tools for targeted drill-downs into mobile networks, as well as to enable quantification of the value of network optimizations in terms of real user QoE.

Within this framework, the primary practical objectives were to:

- build a methodology to monitor Facebook user KPIs, correlate with network statistics and identify bottlenecks
- analyze and improve the Facebook experience in three clusters of XL Axiata’s network
- enable a network-wide view of Facebook application coverage in XL Axiata’s network.

Starting in December, 2013, Ericsson developed a series of metrics that considered the end-to-end network experience impacting app coverage, or, in other words, the key measurable aspects that could go right or wrong in the network when a user is using an app.

These metrics were then measured and gathered in a live network environment in the XL Axiata network during the first six months of 2014. This was done by triggering typical Facebook interactions – using a Facebook-developed test agent and test accounts created for this purpose – on different mobile devices in different regions throughout the XL coverage area. The results were then used to develop new strategies to improve the metrics.

DESIGNING AND PERFORMING THE TESTS
As seen in Figure 3, the methodology developed by Ericsson focused on the following:

1. defining KPIs, test cases (based on typical Facebook use cases) and test tools
2. making preparations for measurements
3. executing the test case
4. analyzing and defining an improvement plan, including analysis of end-to-end bottlenecks and proposed improvement areas
5. executing the improvement plan in a small area of the operator network
6. repeating test cases
7. analyzing improvements.

Specifically for this project, engineers at Facebook developed a custom test agent that was designed for extreme stability and that used the same networking stack as the commercial Facebook app. The Android-based test agent triggered typical Facebook use cases (test cases) by communicating with Facebook content servers in the same ways as the commercial app, and reported user-centric KPIs for a better understanding of the Facebook user experience. The test agent also generated additional data that could be correlated with XL Axiata network statistics in order to determine the link between user experience and network performance.

Figure 3: Methodology used to improve app coverage in the XL Axiata mobile network.
The use cases, illustrated in Figure 4, included feed template download, single and multipicture download and single picture upload – all actions that are performed on the commercial app hundreds of millions of times a day.

The test agent was then loaded onto two types of smartphones – a higher-end model and a lower-end one. Both featured enough compute power to eliminate device limitations as a factor in the testing, while still enabling clear identification of any device-driven differences in user experience.

Simultaneously with the development of the test agent, Ericsson and XL Axiata prepared the network with tracing in the RAN nodes and with network probes for analysis of user plane behavior, among other actions. In addition, for each network measurement, the data was tagged with a number of parameters including time, device and which cell it used. It was also necessary to define thresholds on how to define app coverage within the XL Axiata network. The rough parameter for a download was three seconds.

A total of six devices were then distributed in three clusters – urban, suburban and rural – within the XL Axiata network: Gambir in central Jakarta, Bintaro in suburban Jakarta and Tigaraksa outside Jakarta.

During four measurement rounds between January and June, 2014, the test agent anonymously triggered typical Facebook user interactions in three types of week-long test sessions: stationary tests with the agent running 24/7; drive tests twice a day at high and low traffic times; and “hotspot” stationary tests for three hours per day. The tests resulted in hundreds of thousands of measurement samples.

When the test agent showed a poor user experience, it was then possible to analyze the bad sample and identify where in the network the issues seemed to occur (such as in the RAN, core or CDN) and then dig deeper based on that information.

With this in place, Ericsson and Facebook were able to correlate user-centric KPIs reported by the test agent with network KPIs. This allowed them to develop an outside-in troubleshooting approach, working from actual user experience, not just network data.

The approach can be summarized with the following points:

- understand the user experience – compare Facebook user data from different devices, geographical locations and time of day in order to understand good and bad user experience
- drill down on bad samples – analysis of probe data to understand where in the network problems occur, plus analysis of agent data to understand which types of transactions go wrong, for example, Transport Layer Security setup or object transfers
- drill down on network elements – detailed analysis of statistics and configurations of network nodes and elements to pinpoint bottlenecks and issues
- identification of key bottlenecks – define which key bottlenecks and improvement areas have the highest impact on user experience.
RESULTS AND IMPROVEMENTS

Results from the tests illustrated the impact of device selection and traffic patterns, as well as the correlation between Facebook experience and mobile network traffic load. System-wide bottlenecks and other issues in the RAN, domain name system (DNS) servers and CDN were also identified.

RAN
Issue: In the RAN, problems were found with parameter settings and capacity bottlenecks, as well as due to a lack of features. For example, the higher-end smartphone took significantly longer than the lower-end smartphone to upload photographs, which was due to a parameter settings issue.

Response: Ericsson and XL Axiata performed optimizations of coverage, uplink performance parameters and RAN capacity parameters.

DNS SERVERS
Issue: DNS servers take the domain names of websites and apps and translate them into IP addresses, in order for connected devices to identify each other over the internet. XL Axiata’s DNS servers experienced a high processing load, and measurements from the test agent revealed that this had a significant impact on user QoE. Results showed that objects, such as photographs, might download in 0.5 to 3 seconds, while DNS resolution could skyrocket to 10 to 35 seconds. This delay would render the user experience so bad that the app would appear to be not working.

Response: XL Axiata performed a series of reconfigurations, parameter tunings and capacity upgrades, which have the potential to improve QoE over its entire network.

CDN
Issue: CDNs are used by content providers – including app developers such as Facebook – to deliver content, and they are usually distributed globally. Data in one action can potentially come from multiple locations, and the Facebook test agent recorded content coming to the test devices from as near as Jakarta and as far away as the US, Europe and South America.

This geographic spread had a real impact on QoE. Looking at the worst 10 percent of samples, the local servers, which processed 16 percent of data, had a time to content of three seconds, while more distant servers had a time to content of up to 20 seconds.

Response: In response, Facebook redirected traffic to different servers that were closer and had better connectivity to XL Axiata’s network.

IMPROVEMENTS
After the RAN, DNS and CDN adjustments were performed, there were dramatic improvements in performance on the Facebook test agent.

In order to have the greatest possible impact on user experience, many improvements were focused on fixing the worst performing scenarios. So, for instance, in stationary rural tests on the worst 10 percent of scenarios, time to content was lowered from 9 seconds to 2.8 seconds on the lower-end smartphone.

The final results of the combined changes to the RAN, DNS and CDN showed app coverage improvements of 40 to 70 percent. Within that scope, time to content improved by up to 80 percent, while upload time improved by up to 50 percent.
Mobile networks were first dimensioned primarily to serve voice traffic, but data has decisively overtaken voice and SMS as the primary driver of network traffic. With this in mind, the concept of app coverage should play a central role for operators and app developers alike, as it offers an integrated view of network coverage, capacity and quality relative to a specific app.

However, to date, there have not been adequate KPIs for measuring user QoE on data-centric applications. At the same time, networks in fast-growing emerging markets are often particularly challenged when it comes to data performance.

Ericsson, Facebook and XL Axiata came together to increase the visibility of real user experience and its relation to network capabilities. Facebook and Ericsson together created an innovative methodology and app test agent that – combined with extensive network preparations and monitoring of the XL Axiata network – helped to identify key issues and bottlenecks that affect user metrics, such as time to content within the Facebook app.

These bottlenecks in the RAN, core and CDN were identified by correlating user-centric KPIs with network KPIs (Figure 5). This kind of intelligent correlation and end-to-end understanding of the network then made it possible to understand the user experience in various network conditions.

By addressing these issues, the user experience on the Facebook app in the XL Axiata network was improved substantially, with app coverage rising by 40 to 70 percent. Many of the changes – particularly in the DNS and CDN – have systemic applications that could improve performance across the entire XL Axiata network and for all of Facebook’s mobile users, respectively.

XL Axiata now has the ability to focus network improvements on the areas that impact its users most, and this cost-effective approach to improving network performance positions the company as a data leader within its market. Facebook was able to better understand the many network variables that can impact user adoption, which is especially critical as Facebook and Ericsson work to connect hundreds of millions, if not billions, of unconnected people to the internet.

Finally, Ericsson has developed a replicable model for monitoring, analyzing, measuring and improving app coverage. This model can now be applied to any mobile network to help operators cost-effectively target network improvements in the areas that will have the most impact on user satisfaction, loyalty and retention.

This white paper has been developed in collaboration with Facebook, Inc., and PT XL Axiata Tbk.

ABOUT INTERNET.ORG

Internet.org is a global partnership between technology leaders, nonprofits, local communities and experts, who are working together to bring the internet to the two-thirds of the world’s population that doesn’t have it.

This effort will require two key innovations:
1. bringing down the underlying costs of delivering data
2. using less data by building more efficient apps.
If the industry can achieve a tenfold improvement in each of these areas – delivering data and building more efficient apps – then it becomes economically reasonable to offer free basic services to those who cannot afford them, and to begin sustainable delivery on the promise of connectivity as a human right.

To make this a reality, Internet.org partners, as well as the rest of the industry, need to work together to drive efficiency gains across platforms, devices and operating systems. By creating more efficient technologies, we will be able to speed up the rollout of more sophisticated technologies that provide higher-quality experiences to more people in developing countries, while also enabling the industry to continue growing and investing in infrastructure development. As we work together toward this common goal, we aim to achieve shared learnings and advances that move the industry and society forward.
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDN</td>
<td>content delivery network</td>
</tr>
<tr>
<td>DNS</td>
<td>domain name system</td>
</tr>
<tr>
<td>KPI</td>
<td>key performance indicator</td>
</tr>
<tr>
<td>RAN</td>
<td>radio access network</td>
</tr>
<tr>
<td>QoE</td>
<td>quality of experience</td>
</tr>
</tbody>
</table>
REFERENCES

11. Internet.org, January 2014, Internet.org Efficiency Hackathon [video]. Available at: http://www.youtube.com/watch?feature=player_detailpage&v=7RirBDXGz_w