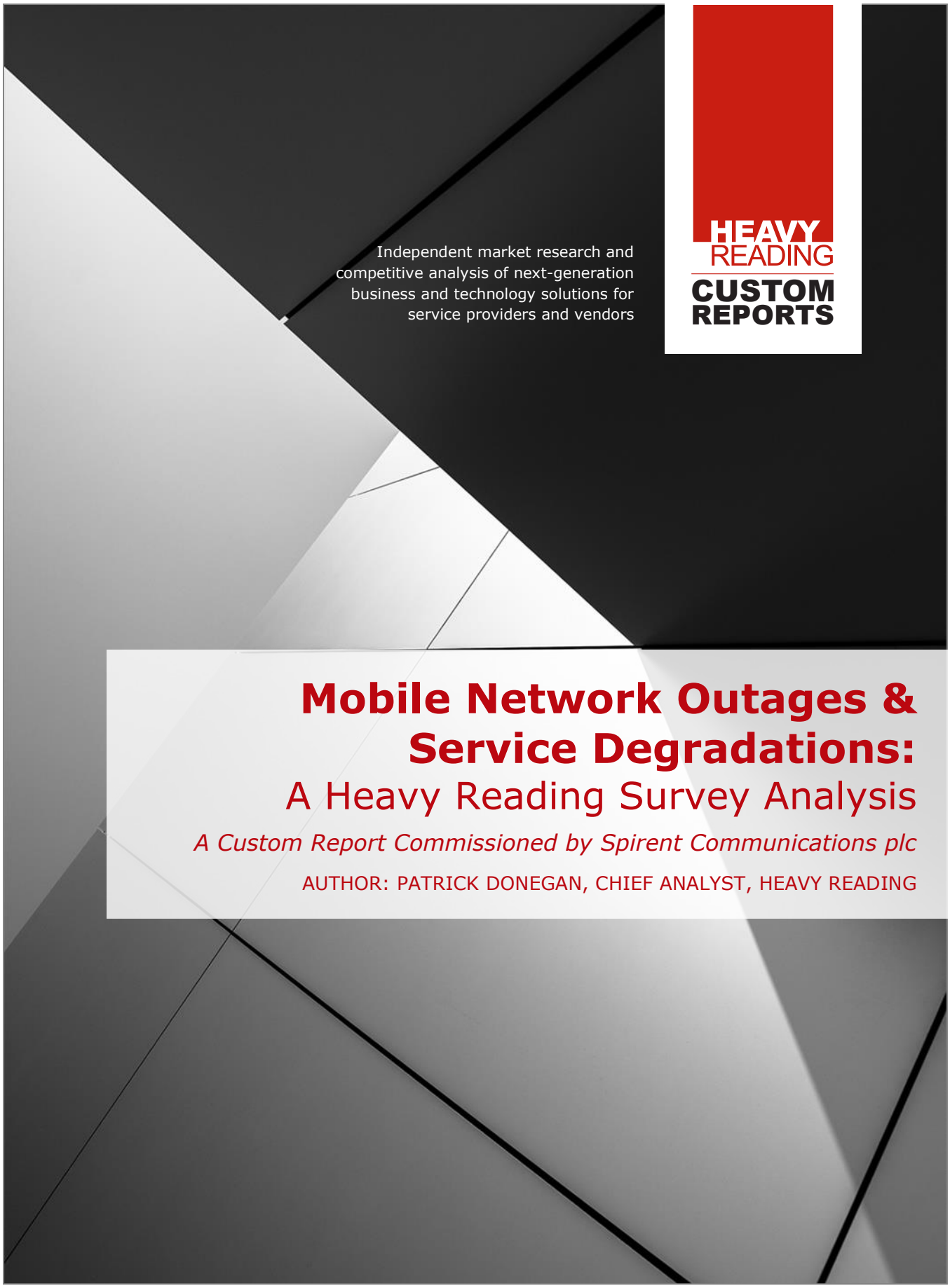

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CUSTOM REPORTS

Mobile Network Outages & Service Degradations:

A Heavy Reading Survey Analysis

A Custom Report Commissioned by Spirent Communications plc

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1. EXECUTIVE SUMMARY

In October 2013, Heavy Reading carried out a survey of mobile operators worldwide on the subject of their visibility into the frequency, causes, and impacts of outages and degradations in mobile networks. A little over two years on, we have undertaken the same survey, repeating many of the same questions used in the original survey, together with some new ones.

The mobile communications ecosystem is not so much undergoing the transformation to an all-IP environment at the network, service and application layers these days. That may have been an accurate description when Heavy Reading's **Mobile Network Outages & Service Degradations** survey was first carried out a little over two years ago, but it's not the case today. Today, the mobile communications ecosystem *is* an all-IP environment – one that is expanding at a furious pace.

In what for the most part still tend to be flat revenue environments for mobile operators, maintaining network availability and excellent service and application performance is exceptionally challenging. That isn't just a function of the huge growth in traffic volumes and generally flat capex budgets. It's also a function of the growing diversity and complexity of application types and their underlying service requirements, and the increasing interdependence of different application, service and infrastructure layers within the network.

Whether it's the challenge of aligning application layer signaling, synchronization packets, security policies, or mapping of different QoS regimes across different network domains, the potential for outages, degradations and a poor user experience in today's environment is inevitably a lot greater than it was – even in the fairly recent past.

Executing flawlessly for millions of highly impatient smartphone users accessing hundreds of thousands of mobile apps, demanding rapid download speeds, and consuming delay-sensitive services such as VoLTE, is infinitely more challenging than it was in the early days of 3G, when most traffic comprised delay-tolerant applications such as Web browsing and email. The days when the traffic mix comprised nearly all voice and SMS seems several worlds away now, although it was still the day-to-day reality for some mobile operators as recently as three or four years ago.

There have been several high-profile network outages over the last year that provide the background context as well as part of the justification for this new study. Some examples are below:

- In January 2016, many Everything Everywhere (EE) and O2 customers in the UK endured prolonged difficulties making and receiving phone calls due to what is understood to have been an issue in the BT network.
- In December 2015, the service of Vodafone UK was disrupted due to the flooding of one of its data centers in Leeds.
- On October 2, 2015, customers of Three (UK) suffered repeated service outages.
- In September 2015, many of Sprint's customers in the U.S. Midwest were unable to make or receive calls and texts for over an hour.
- On September 22, 2015, customers of Croatia's T-Hrvatski Telekom, a Deutsche Telekom subsidiary, were without service for most of the day due to what is understood to have been the effects of a DDoS cyber-attack.

- In August 2015, outages in AT&T's fixed and mobile services were reported across several U.S states for a period of several hours.
- In July 2015, T-Mobile USA agreed to pay the Federal Communications Commission (FCC) a $17.5 million fine as compensation for outages lasting three hours in August 2014, during which emergency 911 services could not be accessed.
- On May 25, 2015, O2 customers in the UK suffered a major outage lasting several hours triggered by a network equipment issue during a network upgrade.
- On April 15, 2015, Vodafone New Zealand customers were unable to use voice, text or data services in several parts of the country.
- In March 2015, KPN, Vodafone Netherlands and T-Mobile Netherlands reported service outages arising from a large-scale power failure in the northwestern part of the country.

This Heavy Reading survey looks under the hood of the mobile network and into the planning, engineering and operations departments of many of the world's mobile operators to gain an understanding of what's going on with respect to network outages and degradations. The survey provides a snapshot of what mobile operators around the world are seeing in terms of the level of disruption to the performance of their networks and the services that run on top of them, what's causing it, and what impact it is having. By leveraging results from the original survey of two years ago, and comparing them with these new results, this survey also provides insight into recent trends in the nature of outages and degradations, the sources of problems, and the nature of the impacts today and over the next couple of years.

Leveraging a survey of 54 online respondents, this report provides timely and unique visibility into how mobile operators are faring as they scale up their 4G networks and embrace ever greater volumes and varieties of traffic. It reveals the frequency with which operators are experiencing outages and degradations in the network and the primary causes of those incidents. It considers the mechanisms, solutions and processes that operators are putting in place to notify them of issues and incidents in the network and then address them. It presents and analyzes the cost to the operator of managing these incidents and looks at the short- and long-term impacts of these incidents on an operator's wider business performance. This survey provides a unique perspective for operators looking to benchmark their performance and processes, as well as for hardware and software vendors looking to better understand their customers' networks, business models and objectives.

1.1 Key Findings

The key findings of this report are as follows:

Aggregating the survey data across sometimes conflicting indicators, it is reasonable to conclude that at a global level the number of incidents in mobile networks is tracking at about the same rate as it was two years ago. On average mobile operators around the world continue to suffer from a network outage or service degradation of some kind roughly once every couple of months.

The most successful operators – representing 30 percent of this year's total survey sample – are managing to keep the number of incidents to between one and three a year or one every several months. The least successful – representing 34 percent of respondents – report at least 15 incidents a year, or one to two per month.

Based on the survey findings we estimate that mobile operators are spending around $20 billion a year dealing with incidents of network outages and service degradations. This represents an 18 percent increase over the $16.9 billion calculated for 2013 in our last survey. This increase is accounted for by an average of 1.7% of annual revenues now estimated by respondents to be being spent on addressing these incidents, up from an average 1.5% estimated by respondents two years ago. It is also explained by the increase in total annual global mobile service revenues from $1.124 trillion to $1.2 trillion over the last two years.

In terms of impacts, the most significant change over the last two years is that mobile operators are now reporting a higher incidence of outages and degradations that take a long time to fix. Whereas in the October 2013 survey 79 percent of respondents reported never encountering a network incident taking 48 hours or more to fix, in this year's survey only 67 percent of respondents gave that answer. Given how very little movement there has been across the two-year period in all the other time windows during which a mobile network is down or its performance is impaired, this 12-point gap does appear to be significant.

Outages and degradations at the level of a specific service remain easily the most frequent. These were cited as the incidents that most frequently impact mobile users by 69 percent of respondents. This compares with 31 percent of respondents that cited network-level disruption that impacts all services simultaneously.

Mobile operators report seeing network failures being the cause of a much higher share of network outages than a couple of years ago. This reflects the increased volume and variety of complex protocol interactions in the mobile network. Whereas they appeared as the third-most common cause of outages in our survey two years ago, network failures rank as the most common cause in this year's survey.

A corollary to the rise in the share of outages accounted for by network failures is a marked decline in the share accounted for by physical link failures. Survey respondents ranked physical link failures as third most common this year, whereas two years ago they accorded them the top spot. Extensive fiber deployment has created the opportunity for more redundant paths in recent years and we believe that this, together with increased adoption of Adaptive Code Modulation (ACM) in microwave links, accounts for a substantial part of the decline in the share of outages caused by physical link failures.

Network congestion emerges as the primary cause of service degradations, just as it did two years ago. This year, however, respondents were even more likely to point the finger at network congestion than they were two years ago.

With some exceptions, degradations in VoLTE service performance appear to be quite rare according to the survey data. Whatever the possible cause of a degradation to VoLTE services, at least 80 percent of respondents considered that it occurs rarely or never. Respondents nevertheless pointed to performance issues in the mobile core as well as in the backhaul network as those that are most likely to trigger a degradation in service.

Most mobile operators need an hour or more following the completion of a network upgrade to be sure – or as sure as it's possible to be – that the upgrade has been

carried out successfully, and with the required functionality and subscriber capacity. Only 11 percent of respondents believe that if everything is looking good after a few minutes, their operations people can relax and assume that all is fine.

Mobile operators seem to have a lot of confidence in the ability of testing and performance monitoring tools to accurately assess how successful a network upgrade has been. Only 9 percent of respondents believe that only the impact of user loading is capable of providing meaningful validation. Performance monitoring systems (59 percent rated most important) and the ability to test in the production network (32 percent) are both highly valued.

More than two thirds of respondents stated that their mobile network does, at least very occasionally, suffer performance impacts triggered by different types of operator partners. The biggest offenders, according to survey respondents, are backhaul wholesalers. 21 percent of respondents stated that these often trigger performance impacts that affect their business, although we suspect that number may actually be understated.

Though they still do not feature prominently in the way most respondents attribute the causes of network outages and service degradations, cyber-attacks feature more prominently in this year's survey than they did two years ago. As an example, this year cyber-attacks registered a few votes when respondents were asked to identify the most important causes of service degradations. In the October 2013 survey, cyber-attacks didn't register a single response to this question.

1.2 Survey Methodology

This report is based on **Heavy Reading's 2016 Mobile Network Outages & Service Degradations Survey**, a Web-based survey of network operators around the world conducted in January 2016. Respondents were drawn from the network operator list of the Light Reading database. Before starting the survey, all respondents were shown the following statement:

The objective of this survey is to understand the impact and implications of both outages and degradations in the mobile network. Throughout the survey, the term "network outages" refers to occasions when the mobile network is down and/or inaccessible or unavailable to users, or when access to specific services, such as Internet access for Web browsing, are unavailable for a period of time. The term "service degradation" is used to mean occasions when network access to all services or even specific services is severely degraded in a way that impacts the customer experience, so that response times are very slow, all service or specific access is limited or intermittent while other services remain generally accessible.

As shown in **Figure 1** a total of 54 qualified mobile operator provider respondents participated in the survey. Respondents that did not work for an operator that has a mobile license were rejected and were not admitted to the final survey of 54 qualified respondents.

Figure 1: Respondents by Service Provider Type

Service Provider Type	% of Respondents
An operator that offers both wireline and mobile service	78%
A pure-play mobile operator	22%

N=54

Figure 2 details the job functions of the qualified respondents in the survey.

Figure 2: Respondents by Job Function

Job Function	% of Respondents
Engineering	27.8%
Network planning	20.4%
Corporate management	14.8%
Network operations	13%
Service operations	7.4%
Sales & marketing	3.7%
Finance	0%
Other	13%

N=54

Figure 3 shows the breakdown of qualified respondents by the geographic location of the company's headquarters. The U.S. provided the largest number of responses, with 52 percent of respondents. Europe and Asia account for 11 percent and 13 percent, respectively, while the Middle East/Africa and South America account for 8 percent and 7 percent, respectively.

Figure 3: Respondent Breakout by Geographic Location

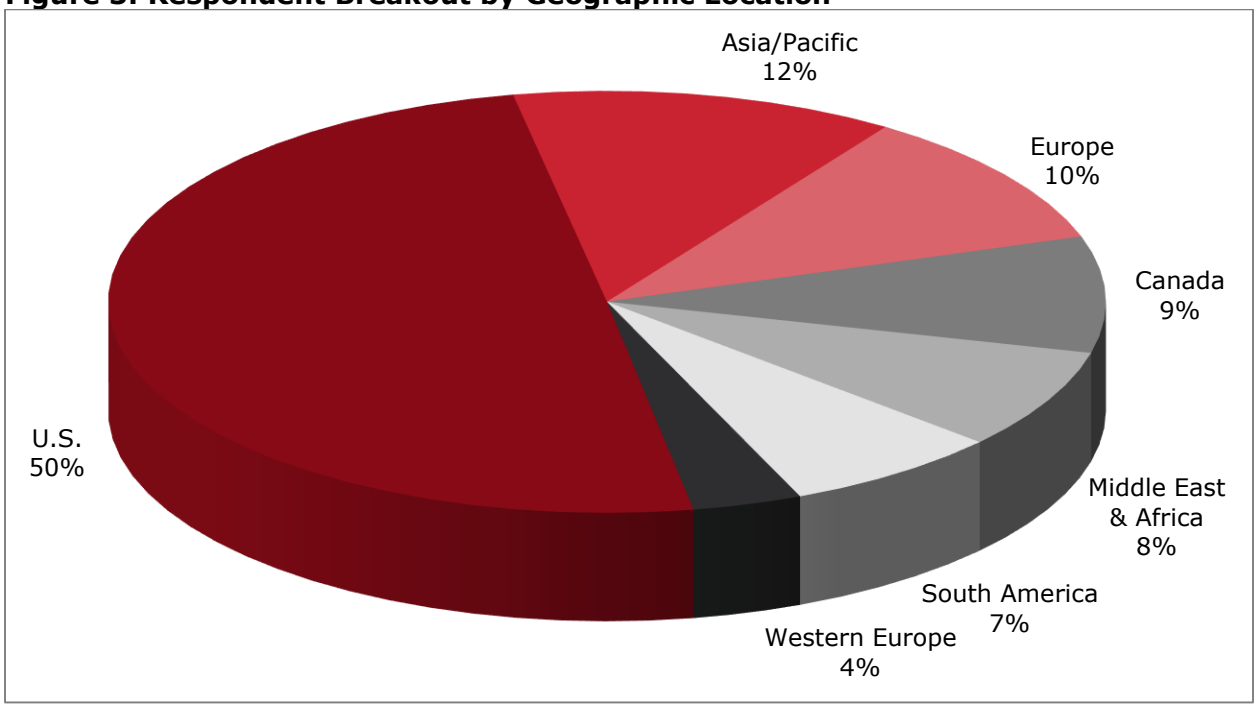

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Figure 4 shows the breakout of qualified respondents by the company's annual revenue. 40 percent of respondent's companies have annual revenues in excess of $5 billion. Nearly two thirds have annual revenues in excess of $1 billion.

Figure 4: Respondent Breakout by Company Annual Revenue

Annual Revenue	% of Respondents
Less than $50 million	5.6%
$50 to $200 million	13%
$200 to $500 million	9.3%
$500 million to $1 billion	9.3%
$1 billion to $5 billion	22.2%
More than $5 billion	40.7%

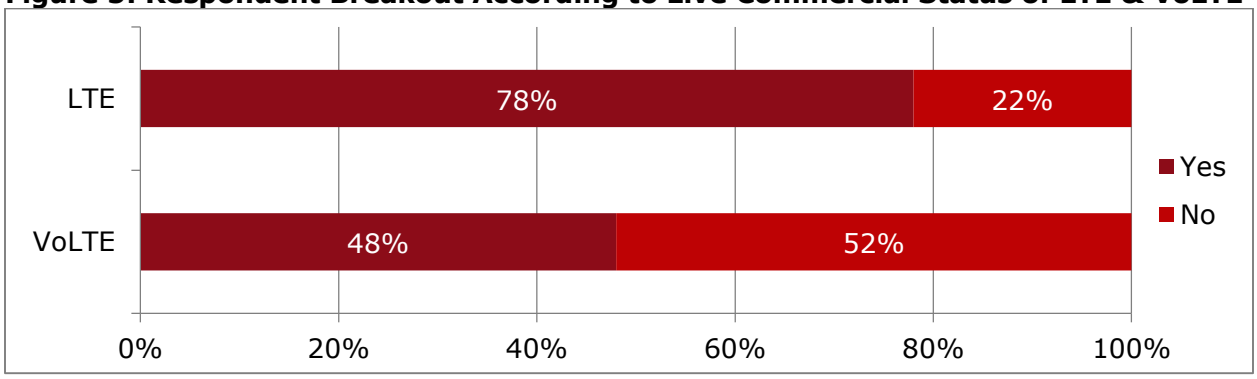
N=54

Figure 5 shows the breakout of qualified respondents according to whether they have already rolled out LTE and VoLTE respectively as a commercial service.

More than three quarters of respondents to the survey work for operators that have LTE in live commercial service. Almost half also have Voice over LTE (VoLTE) in live commercial service. As with our October 2013 survey, this year's survey yielded no meaningful delta between the reported experiences and forward looking outlooks of respondents from those operators that already offer LTE as a commercial service and those who don't.

In October 2013 it was legitimate to wonder whether the performance of what were then mostly lightly-loaded LTE networks might deteriorate significantly as they scaled up. As shown in the subsequent analysis around this year's survey data, the number of incidents appears to have remained roughly constant.

Figure 5: Respondent Breakout According to Live Commercial Status of LTE & VoLTE



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In the remainder of this report, we analyze the results of **Heavy Reading's 2016 Mobile Network Outages & Service Degradations Survey**, exploring trends in the frequency and type of mobile network outages and service degradations, followed by their causes and consequences. The report concludes with the complete text of the survey questionnaire.

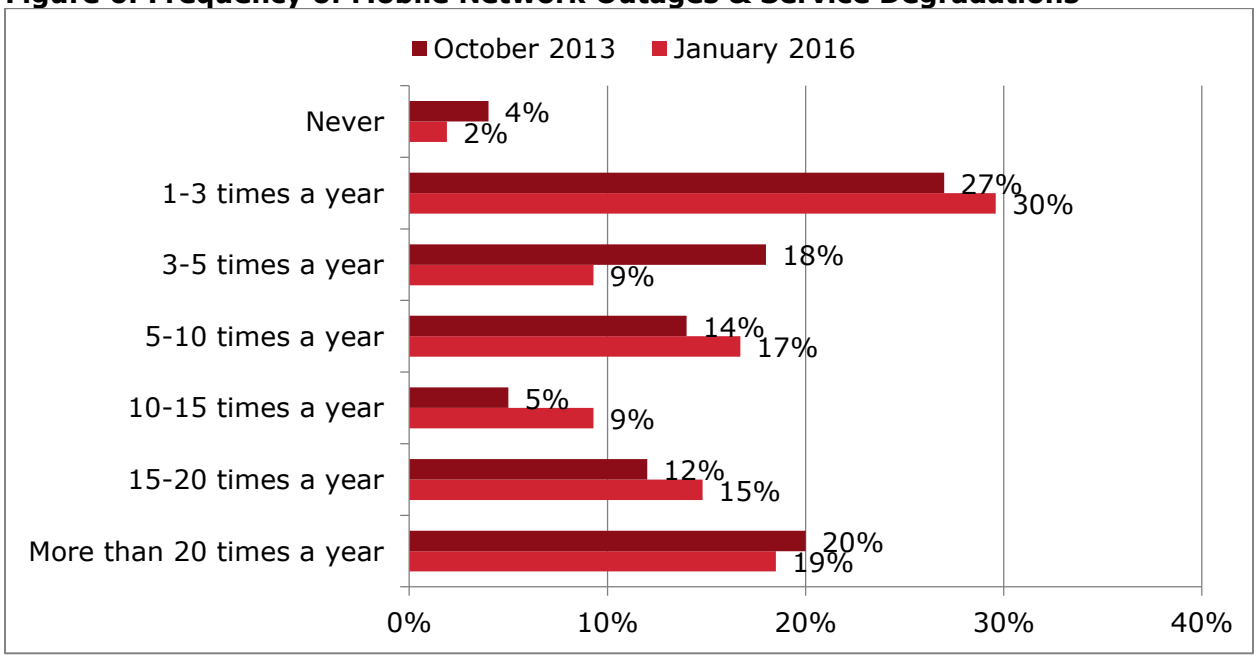
2. TRENDS IN OUTAGES & SERVICE DEGRADATIONS

Network outages and service degradations are a fact of life in operating a mobile network. With the total number of mobile connections now exceeding the world's human population, this is hardly surprising. Sometimes, these incidents make it into the public domain. When operators suffer significant outages that impact a large number of subscribers, this information makes its way into the media, in no small part due to the rise of social media. When a network or service is down or delivering poor performance, many of today's consumers will turn to social networking sites to share their experiences and vent their frustration. And of course, there are also many smaller-scale outages and service degradations that impact fewer subscribers, or impact them less dramatically, with the result that they never make it in to the public domain.

Figure 6 shows how this year's survey respondents reported how frequently their companies are suffering from outages and degradations compared with the reported experience of the 2013 survey sample.

As supported by the data, it's still the case that hardly any mobile operator gets through a year without being impacted by an outage or degradation. The most successful operators – representing 30 percent of this year's total survey sample – are managing to keep the number of incidents to between one and three a year, or one every several months. The least successful, representing 34 percent, report at least 15 incidents a year, or one to two per month.

Figure 6: Frequency of Mobile Network Outages & Service Degradations



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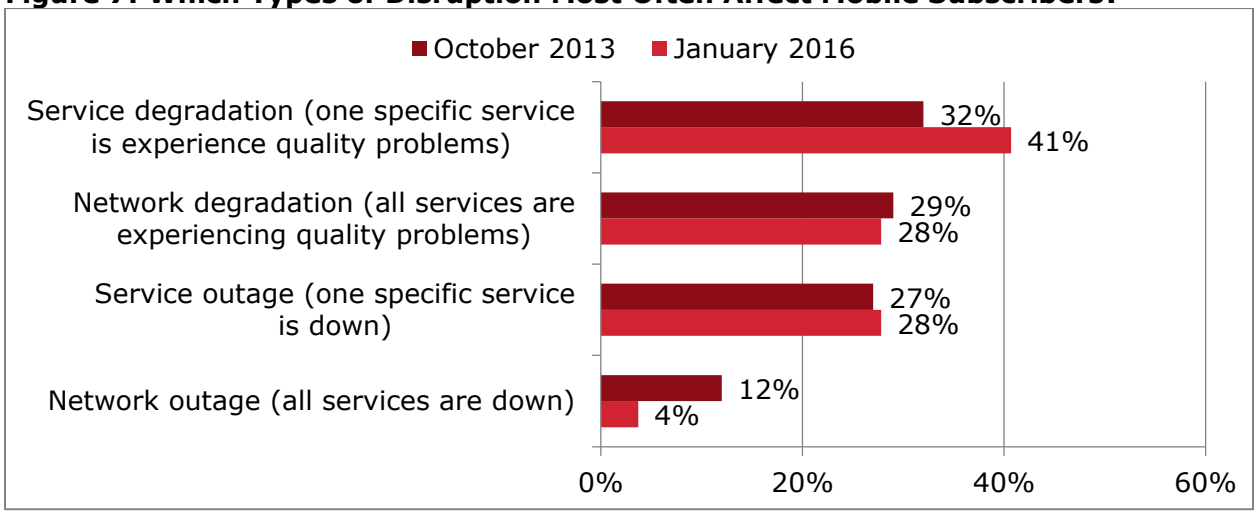
At a global average of 5.7 incidents per year per mobile operator, the data suggests that the number of incidents being endured is up 12 percent on the average 5.1 yielded in the October 2013 survey. The margin of error in this survey sample probably does not allow for that figure to be adhered to too rigidly, however, particularly when considered in conjunction with **Figure 7**.

Figure 7: Which Types of Disruption Most Often Affect Mobile Subscribers?



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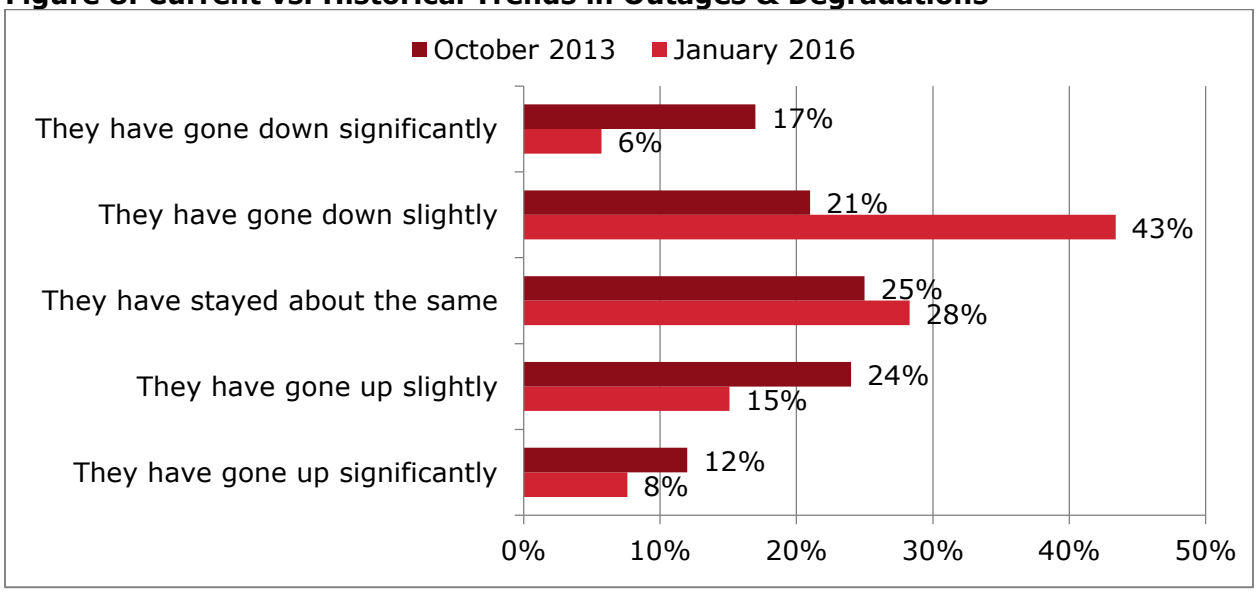
As shown in **Figure 8**, outages and degradations at the level of a specific service are easily the most frequent. These were cited as the incidents that most frequently impact mobile users by 69 percent of respondents compared with 31 percent of respondents that cited network level disruption that impacts all services simultaneously.

Figure 8: Current vs. Historical Trends in Outages & Degradations



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Comparison with the October 2013 survey results points to the conclusion that service-specific disruption accounts for a higher share of incidents today than two years ago. The 69 percent pointing to these issues creating the largest number of incidents compares with 59 percent last time. Consistent with that, the data also points to the share of disruption caused by outright outages receding and the share accounted for by network and service degradations increasing. 69 percent of respondents cited degradations rather than outages in this year's survey compared with 61 percent in the October 2013 survey.

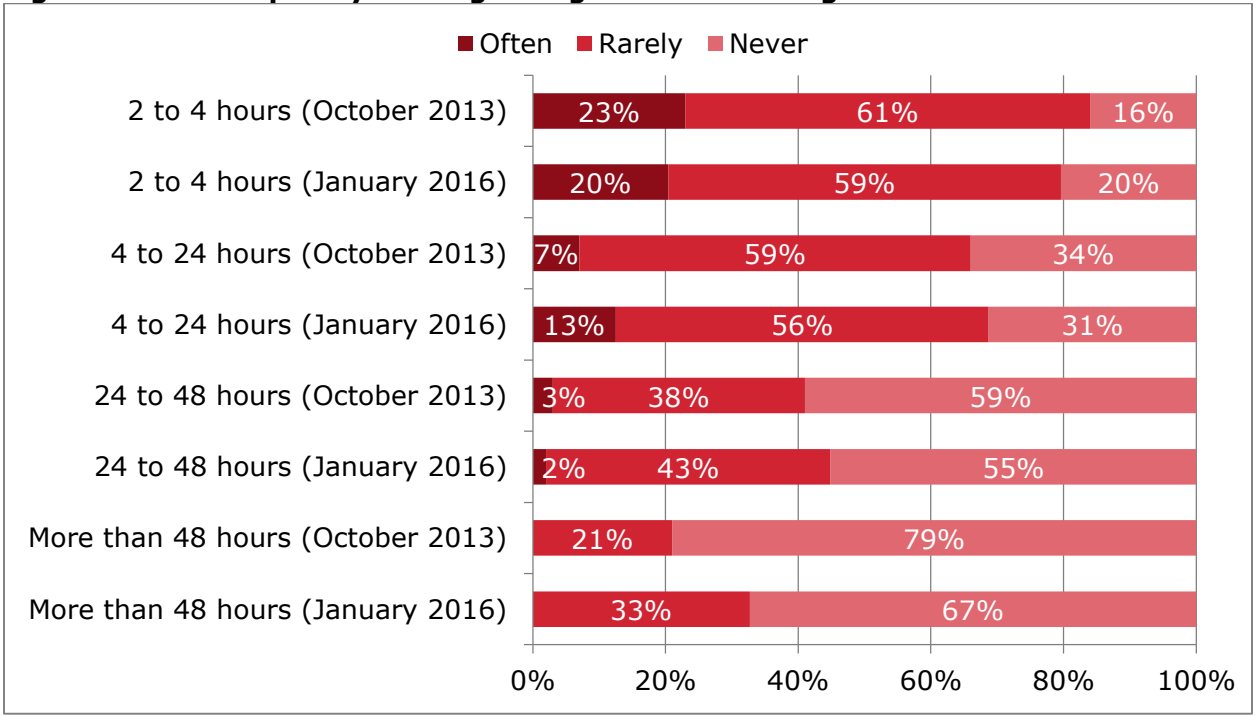
This appears to reflect the growing share of applications in the mobile network that have unique and specific service requirements whether with respect to speed, latency or other underlying service requirements that degrade the user experience when they are not met.

Whereas **Figure 6** suggests a slight increase in the number of incidents of outages and degradations over the last couple of years, **Figure 8** actually suggests the contrary – a slight reduction. Whereas two years ago only 38 percent of respondents reported the number of incidents falling, in this year's survey this was the view of 49 percent of respondents (although the vast majority of those also reported incidents falling slightly rather than significantly). Similarly only 23 percent of respondents reported that incidents are up in the most recent survey, compared with 36 percent two years ago.

There is nothing inherently troubling about this apparent contradiction between **Figure 6** and **Figure 8**. The shifts in perception aren't very large in either case. In the case of **Figure 6** in particular, the outcome is within a margin of error. Considering the conflicting results arising in **Figures 6** and **8** it seems reasonable to conclude that from a global perspective the number of incidents currently impacting mobile networks on a daily basis on average as of January 2016 is approximately the same as two years ago.

This was also the conclusion of the October 2013 survey when a little more than a third (36 percent) of operators believed that the number of incidents had gone up, 38 percent believed they had gone down and 25 percent believed they had stayed about the same. That being the case, it strongly suggests that as a global average, reflecting the often extreme differences in the records of advanced and not so advanced operators throughout the world, the volume of network outages and degradations in mobile networks has remained approximately constant for each of the last four years.

Figure 9: The Frequency of Long Outages & Service Degradations



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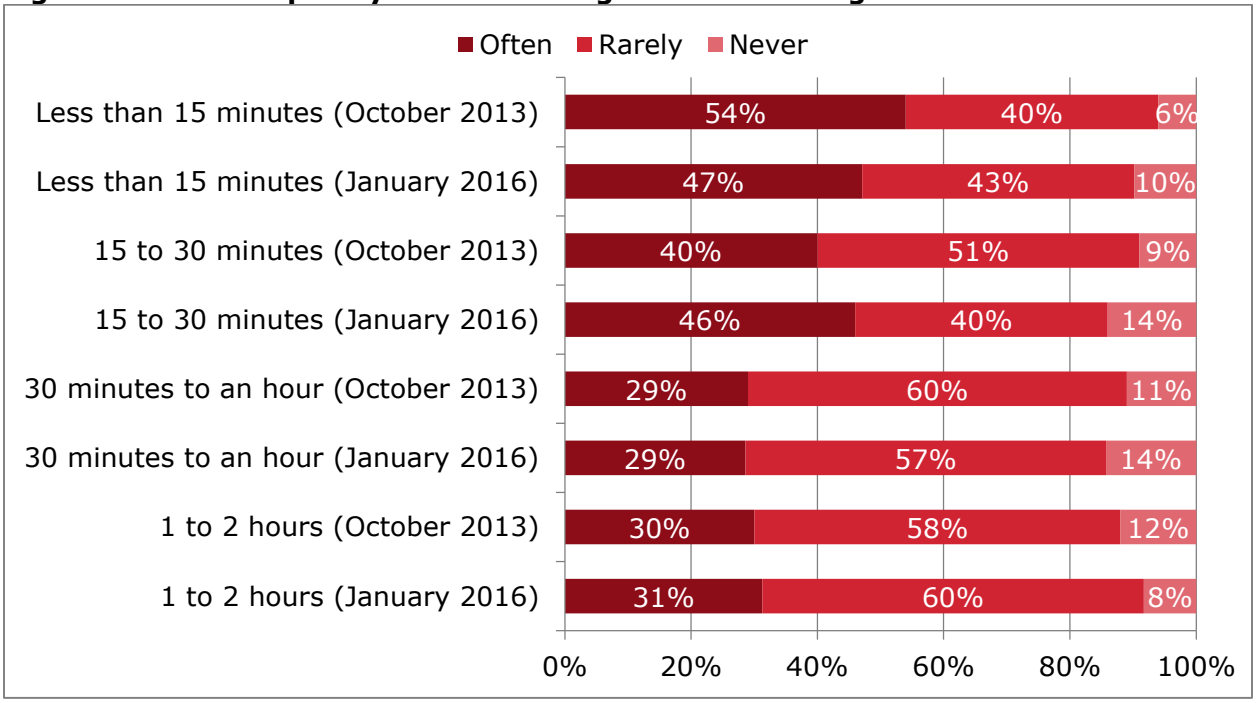
Whereas **Figures 6** and **8** each suggest a slight movement in the number of instances of outages and degradations over the last two years, **Figures 7** and **8** point clearly to an essentially flat incident environment with virtually no change.

As shown in **Figure 9**, outages and degradations lasting two hours or more continue to be rare. 55 percent of respondents still say that their network never suffers an outage lasting more than 24 hours. 31 percent still say that their network hasn't suffered an outage or degradation lasting more than four hours. Only one in five respondents stated that their company often suffers from significant outages or degradation lasting two or more hours – almost exactly the same proportion as two years ago. Indeed, if one compares the 2013 survey responses with this year's across **Figures 9** and **10**, it is striking how closely aligned they are.

Arguably the single most important delta arising in **Figures 9** and **10** is at the bottom of **Figure 9** and in relation to the frequency with which respondents report seeing incidents that last for two days or more. Whereas in the 2013 survey 79 percent of respondents reported encountering no such incidents in their network over the previous two years, in this year's survey only 67 percent of respondents gave that answer. Given how remarkably all the other results across different categories barely shift at all between the 2013 and 2016 surveys, the 12-point gap does appear meaningful here. It suggests that while they are still extremely rare, the number of incidents taking 48 hours to resolve may be increasing.

Figure 10: The Frequency of Short Outages & Service Degradations



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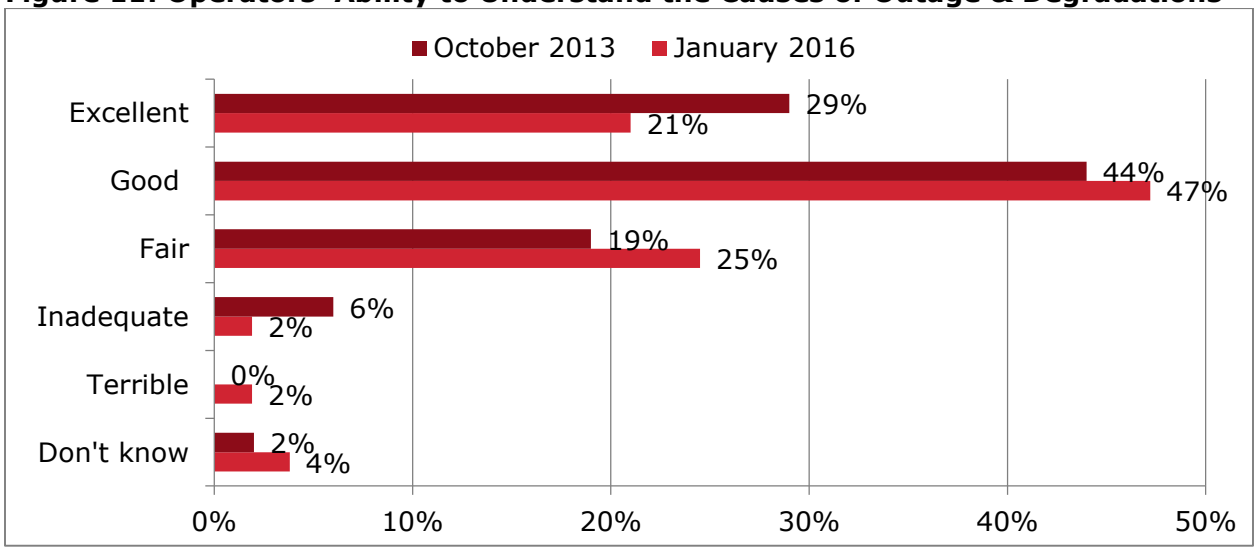
One factor coming into play here may be the push out from 90 percent population coverage into the remotest geographies of some markets to reach the last couple of percentage points of the most remote populations. In these virgin areas, which many operators are only now serving for the very first time, it can often take a very long time to deploy resources to fix a problem that would take a much shorter time to fix in the more hospitable environments that mobile operators have typically served.

3. CAUSES & COSTS OF OUTAGES & DEGRADATIONS

Most operators acknowledge some level of challenge in identifying the root cause of outages. Due to varying levels of investment and operational competence, some operators can identify most causes of incidents quite quickly, whereas others can take much longer, don't bother or even give up halfway through an investigation because they're presented with new fires to fight.

Figure 11: Operators' Ability to Understand the Causes of Outage & Degradations



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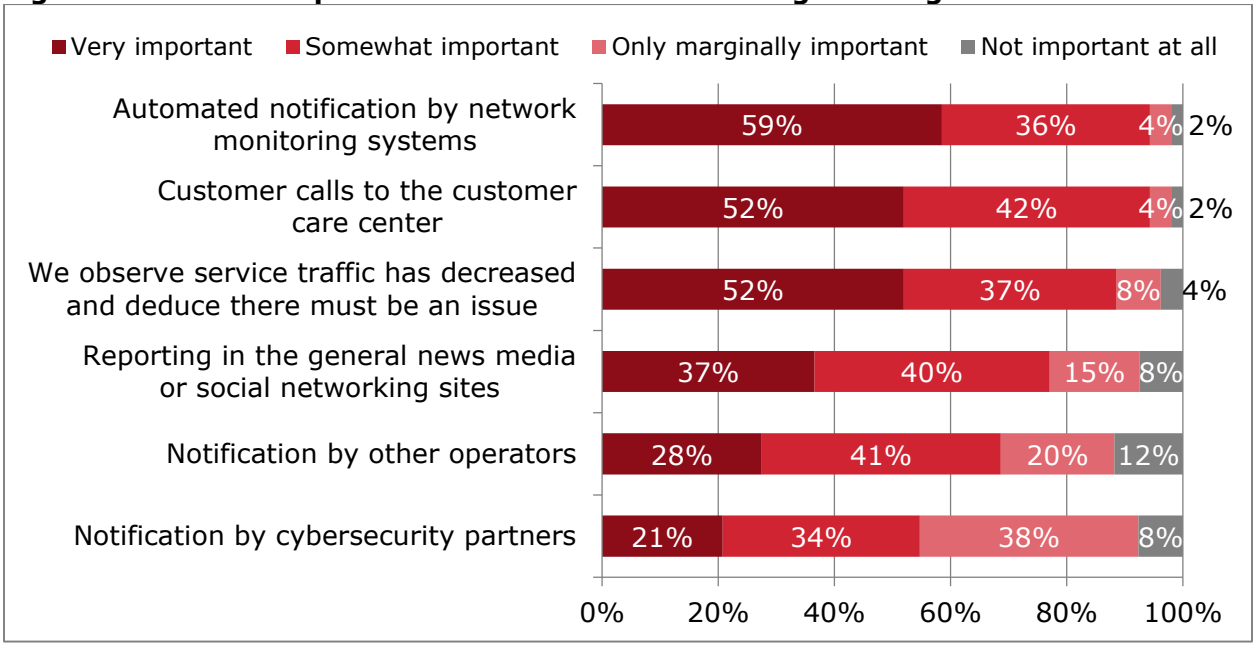
Although **Figure 12** suggests a strong commitment on the part of mobile operators worldwide to identifying and fixing outages and degradations, **Figure 11** suggests that their ability to understand the causes of these incidents hasn't actually moved much over the last two years.

The 21 percent of respondents that stated this year that their company has an excellent ability to understand the causes of incidents is actually 8 percent down on the 29 percent that said the same thing two years ago. Balancing it out to the point where there is virtually no change from two years ago, those 8 percentage points are nevertheless assimilated by slightly higher scores this year among those citing a fair or good means of understanding the causes.

Mobile operators continue to rely on multiple inputs for becoming aware of outages and degradations. They depend most of all on automated notification by network monitoring systems, customer calls to the customer care center and making deductions based on their own observations of service traffic.

The scores for each approach correlate very closely with the 2013 survey results with one single exception. Whereas 35 percent of respondents rated making deductions based on their own observations of service traffic as very important in 2013, this time round 52 percent rate this approach very important. This suggests a trend towards greater leveraging of available network reporting in pursuit of both mitigating network incidents and avoiding them in the first place.

Figure 12: How Do Operators Become Aware of Outages & Degradations?



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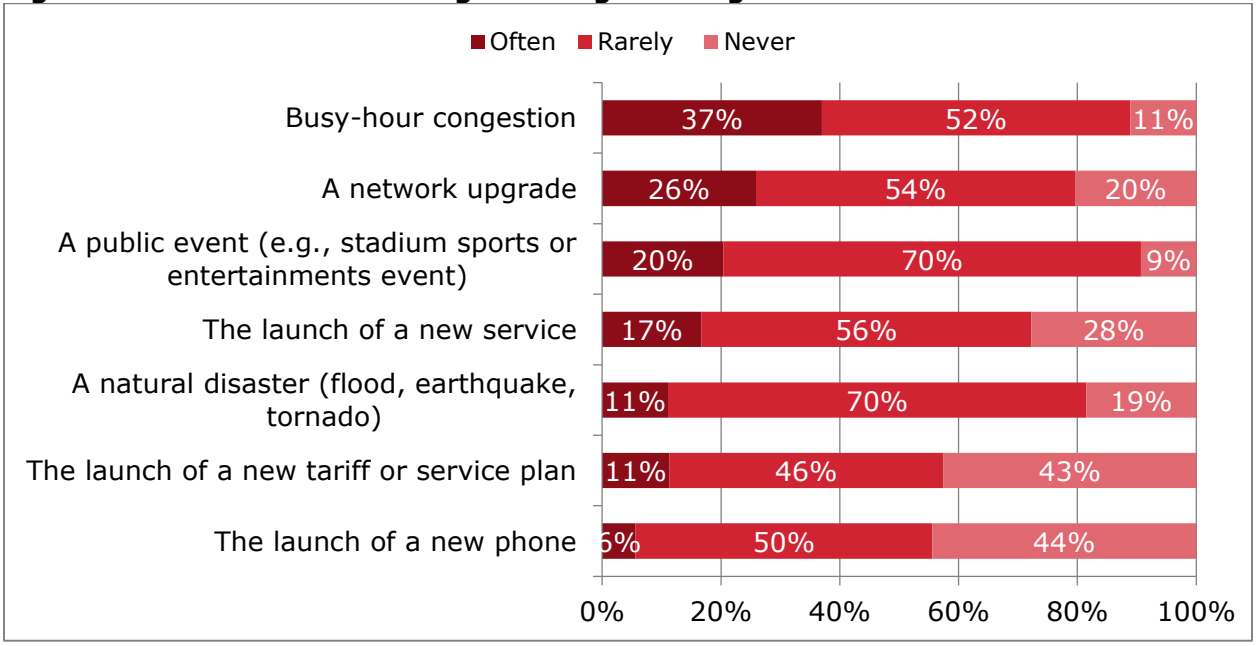
Some level of dependency on the customer care center is inevitable simply because no matter how advanced the operator is in detecting issues via the monitoring systems, there will be plenty of occasions when it takes more than half an hour to fix it, in which case the customer care calls will inevitably come in. The objective for the operator is to lessen that dependency, reduce the volume of calls and reduce the duration of those calls by equipping customer care staff with a ready-made explanation and prognosis as soon as possible.

Figure 13: Factors Contributing to Outages & Degradations



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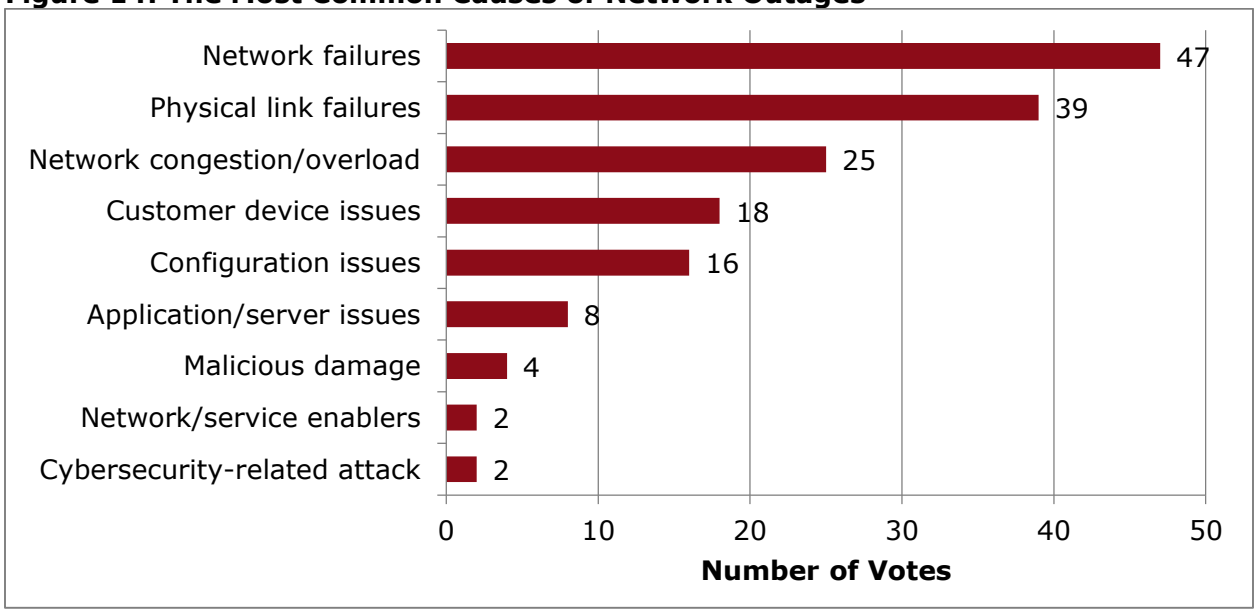
Subsequent figures identify the primary causes of network outages and degradations. **Figure 14** provides the survey sample's outlook with respect to some factors that tend to contribute to some network incidents.

As shown, easily the biggest offender is "busy hour" congestion, reckoned to often feature as a contributory factor in network incidents by 37 percent of respondents. Network upgrades – which triggered the major outage lasting several hours suffered by O2 in the UK in May 2015 – polled second and public sporting or entertainment events ranked third.

Just how high risk these events remain is illustrated by the fact that in all three cases no more than 20 percent of respondents were able to say that they never contribute to a network incident these days. It's also noteworthy that no matter the issues that are sometimes caused by the launch of new phones (for example with unexpected or unpredictable signaling behavior), the risk of network incidents being caused by the launch of a new phone is a lot less than the greater end-to-end complexity associated with the launch of a new service.

Network failures, which generally refer to the interaction of different networking protocols across different network elements and network domains, emerge as the single most common cause of network outages, as shown in **Figure 14**. Reflecting as it does the increased volume and variety of complex protocol interactions in the mobile networks, this is unsurprising.

Figure 14: The Most Common Causes of Network Outages



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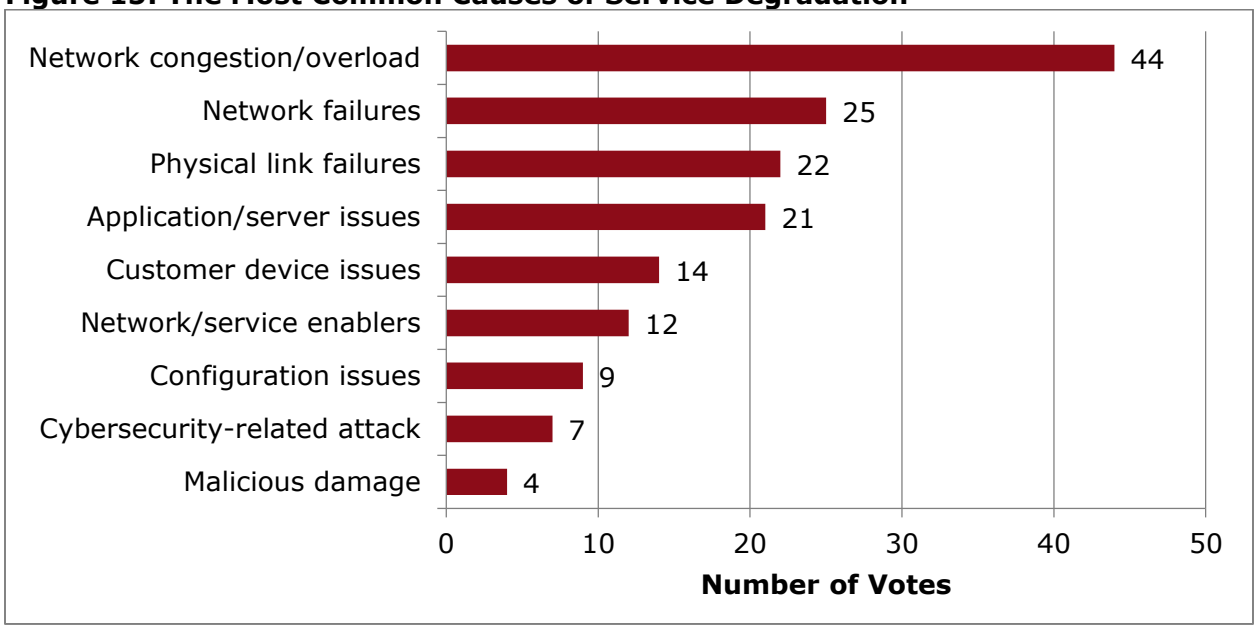
As this survey question registered a number of votes (up to two per respondent) in both 2016 and 2013 surveys, an apples-to-apples comparison is inappropriate due to the smaller survey sample generated for this year's survey. Nevertheless, a high-level comparison with the October 2013 survey response to this same question is interesting and instructive.

In October 2013 network failures registered the third-largest number of votes, behind network congestion overload in second place. Physical link failures were identified as the most common cause of network outages. Back then physical link failures registered 57 votes in first place, compared with 41 for network failures in third.

In this year's survey, network failures has taken top spot on 47 percent with physical link failures back on 39 percent. This is quite a turnaround but it has as much to do with the lessening vulnerability to physical link failures as it does to the growing vulnerability to network failures amidst increasing complexity.

Specifically, extensive fiber deployment has created the opportunity for redundant paths in recent years. Even though Metro Ethernet and MPLS networks have had restoration capabilities for a while, redundant physical paths always help. Redundancy and restoration capabilities may not be all that high a priority in the rush to provide connectivity, but the emphasis for many operators now is shifting toward wanting more stable networks as well. We believe that this, together with increased adoption of Adaptive Code Modulation (ACM) in microwave backhaul links has been a major contributor.

Figure 15: The Most Common Causes of Service Degradation



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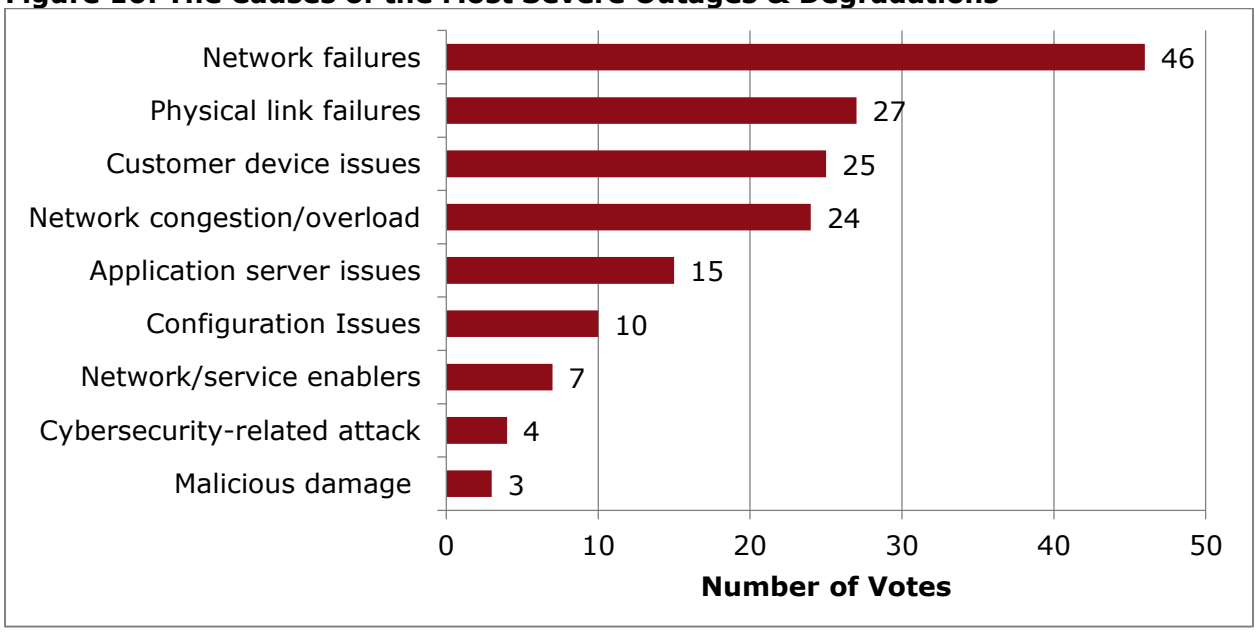
Like **Figure 14**, **Figure 15** lends itself to high-level rather than granular apples-to-apples comparison with the October 2013 survey outcome.

Network congestion emerges as the primary cause of service degradations, just as it did two years ago. This year, however, respondents were even more likely to point the finger at network congestion than they were in the earlier survey. Two years ago network congestion came top with 49 votes, closely followed by physical link failures in a close second place on 44. This year network congestion is overwhelmingly identified as the primary culprit on 44 votes, with network failures coming a very distant second on 25.

Consistent with **Figure 14**, **Figure 15** shows respondents sharing their perception of a growing threat to service performance posed by network failures and a somewhat lessening threat posed by physical link failures. Network failures ranked fifth as a cause of service degradations two years ago but ranks second now. Physical link failures ranked second (and close to first) two years ago but now ranks third on just half the number of votes registered by what respondents see as the primary cause.

Also of interest, cyber-attacks registered seven votes this year. Despite a higher turnout of respondents two years ago, cyber-attacks didn't register at all on that occasion. This likely reflects growing awareness of the impact on network performance of spam and Distributed Denial of Service (DDoS) attacks as well as misbehaving applications. One such documented case occurred on September 22, 2015, when customers of Croatia's T-Hrvatski Telekom, a Deutsche Telekom subsidiary, were without service for most of the day due to what is understood to have been the effects of a DDoS attack.

Figure 16: The Causes of the Most Severe Outages & Degradations



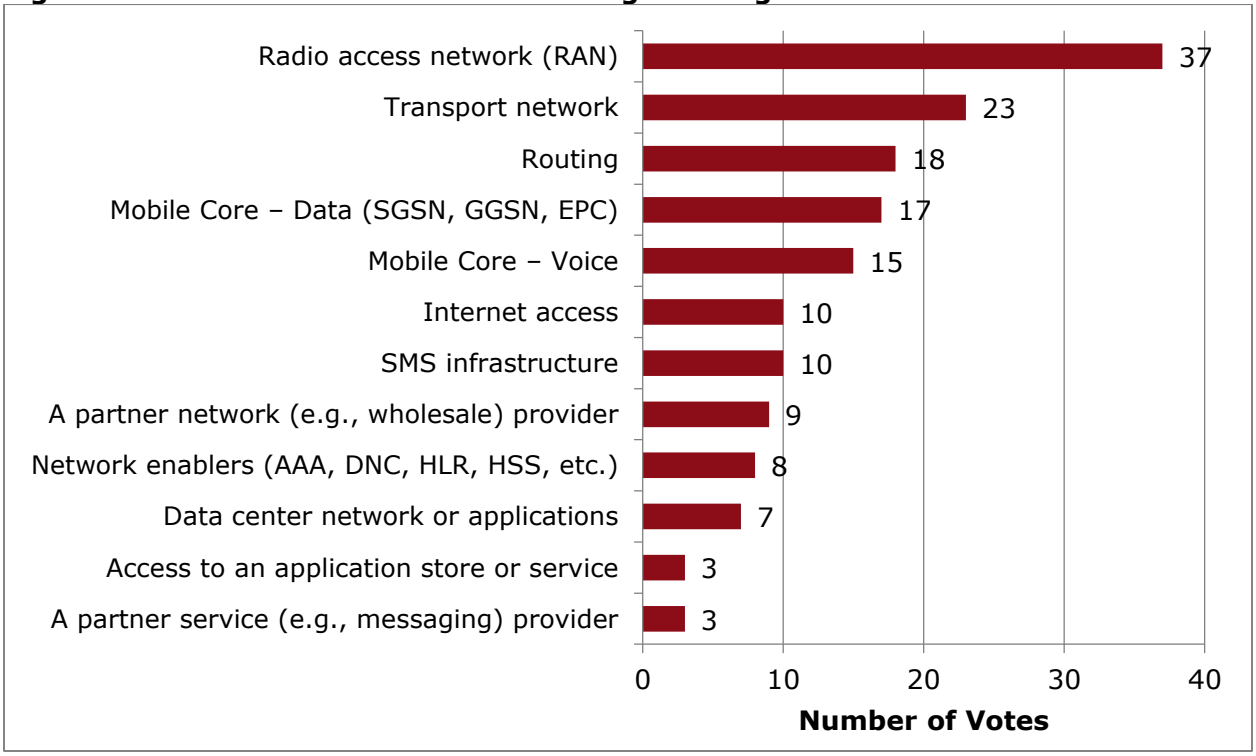
N=54

Network failures already had the status of causing the most severe outages and degradations back in the October 2013 survey. As also shown in **Figure 16**, however, they emerge as a still greater threat to network uptime and performance now than they were back then. Two years ago, network failures registered a top score of 48 votes as responsible for the most severe incidents, narrowly ahead of network congestion at 45. This year it registers 46 votes, far ahead of physical link failures in second place at 27 votes.

As we identified in our survey two years ago, it is outages and degradations caused by network failures that operators tend to report as taking the longest time to identify, understand and fix. Failures arising in physical links and network congestion can certainly have an impact that is as devastating, or even more devastating, for the duration that it takes to fix them. But these can typically (though not always) be diagnosed and remediated more quickly than network failures. Clearly, that gap between the severity of the threat posed by network failures – and that posed by other flaws in the way the network is engineered and operated – is growing markedly.

Unsurprisingly, and as in our October 2013 survey, **Figure 17** shows that outages and degradations continue to occur most often in the RAN. The reasons for this are obvious: there are many more cell sites than other type of network elements in the mobile network. The RAN is also necessarily more bandwidth constrained by spectrum limitations, rendering it more susceptible to causing service degradations.

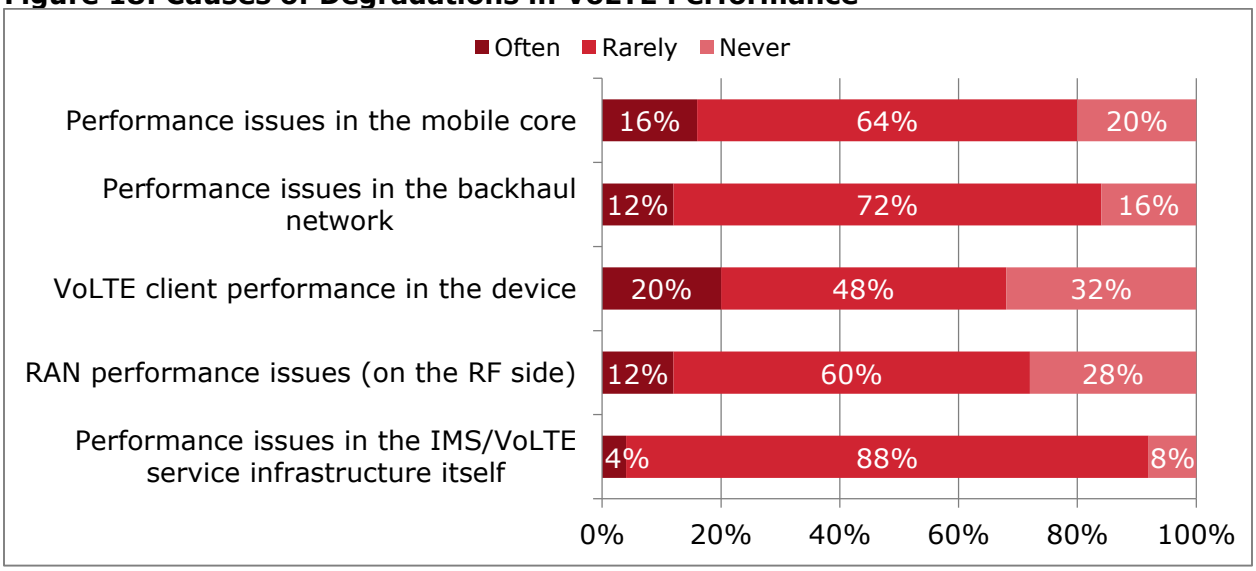
Figure 17: Network Domains Where Outages & Degradations Occur Most Often



N=54

As shown in **Figure 18**, a large majority of the subset of survey respondents whose companies are currently offering VoLTE service reported that degradations in VoLTE service performance are typically quite rare. Respondents nevertheless pointed to a number of causes that can trigger degradations, among which performance issues in the mobile core and in the backhaul network emerge as the most common.

Figure 18: Causes of Degradations in VoLTE Performance



N=25 (respondents whose companies are already offering VoLTE services)

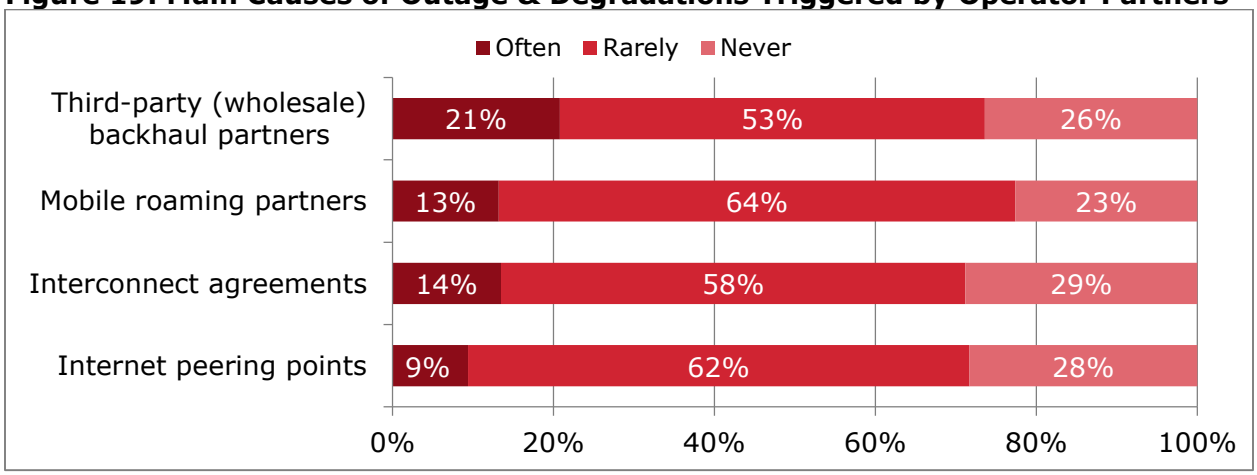
Although client performance in the device registered the highest score for often triggering degradations in performance by a narrow margin, respondents were nevertheless very much more likely to report that issues with the VoLTE client never impact performance compared with performance issues in the mobile core or backhaul. 32 percent of respondents reported that VoLTE client never triggers performance issues compared with just 20 percent who said the same of the mobile core and just 16 percent who said the same of the backhaul.

Figure 18, relating to VoLTE, aligns well with **Figure 15**, which identified network congestion and network failures as the most frequent causes of service degradations in general. There are two specific challenges with VoLTE that have to be navigated with attendant risks of network failures and network congestion in order to ensure a good quality user experience. One is the prioritization of VoLTE packets at times of network congestion. The other is managing latency in each direction rather than just as a conventional round trip metric.

Mobile networks sometimes suffer degradations and outages that are triggered by other service provider partners. As recently as January 2016, for example, many Everything Everywhere (EE) and O2 customers in the UK endured prolonged difficulties making and receiving phone calls due to what are understood to have been an issue problems in the BT network.

As shown in **Figure 19**, more than two thirds of respondents stated that their mobile network does, at least very occasionally, suffer performance impacts triggered by all four of the partner operator types listed. The biggest offenders, according to survey respondents, are backhaul wholesalers. 21 percent of respondents stated that these often trigger performance impacts that affect their business.

Figure 19: Main Causes of Outage & Degradations Triggered by Operator Partners



N=54

There are three notable things about this. The first is that this finding aligns very well with **Figure 17**, which identifies the RAN and transport networks as the domains where network incidents arise most frequently.

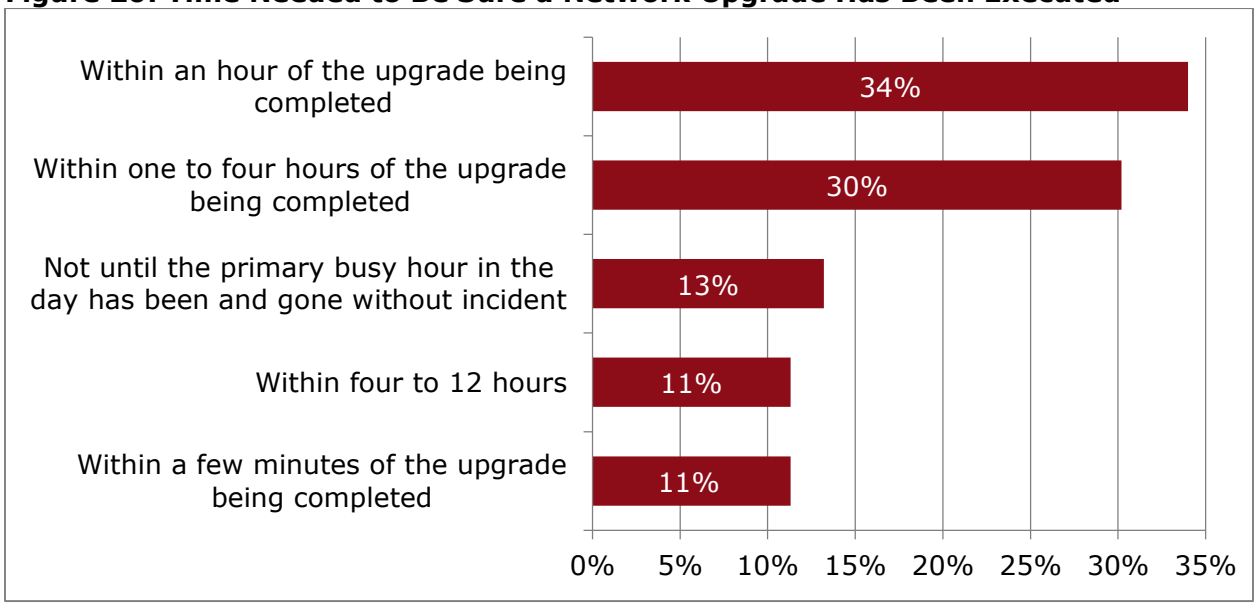
Second, in cases where mobile operators are highly dependent on leasing backhaul services rather than building their own, it's likely that backhaul wholesalers account for an even larger share of the incidents caused by partner operators than is suggested by the data. This is because a lot of mobile operators, most notably in emerging markets, but also in western Europe, lease very little backhaul from third parties or indeed don't lease any at all.

Since a significant number of mobile operators matching this profile are bound to have been among the survey sample, it's a safe bet that a sub-sample of respondents, all of whom do use backhaul wholesalers, would have identified backhaul wholesalers as the primary offender among their operator partners by an even greater margin.

That said, a third aspect of this is also worth noting. Backhaul wholesalers emerge as the most frequent offenders but it's unlikely that they are responsible for the most severe network incidents as they often impact only a segment of the network. Interconnect and Internet peering partners are more likely to bear responsibility for those, given that they can often impact larger numbers of subscribers.

As shown in **Figure 20**, most mobile operators need an hour or more following the completion of a network upgrade to be sure – or as sure as it's possible to be – that the upgrade has been carried out successfully, and with the required functionality and subscriber capacity. Only 11 percent of respondents believe that if everything is looking good after a few minutes, they can assume that all is fine. Including this 11 percent who are either clear market leaders or eternal optimists, a total of 45 percent of respondents believe it's possible to relax within an hour of a network upgrade appearing to have gone successfully.

Figure 20: Time Needed to Be Sure a Network Upgrade Has Been Executed

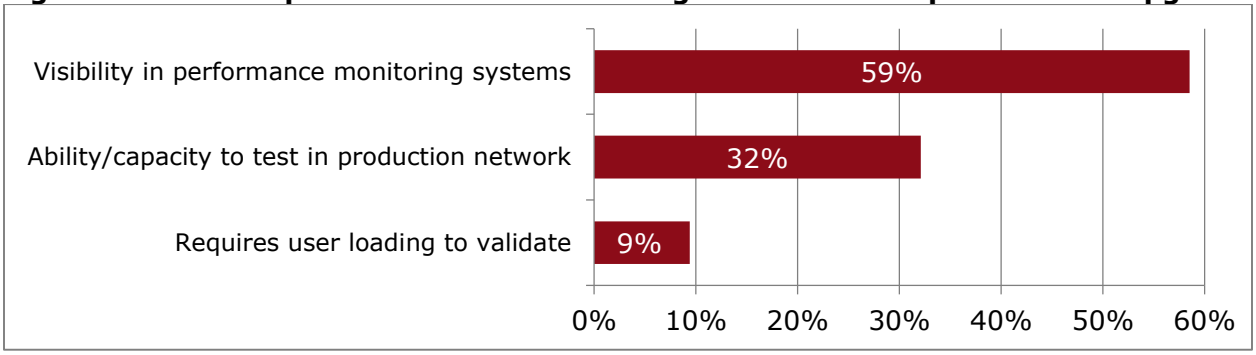


N=54

55 percent of respondents dare not believe all is okay until at least one hour has elapsed. A combined 24 percent of respondents feel the need to keep their fingers crossed and hope for the best for at least four hours or until the next primary busy hour following the upgrade has been and gone without incident.

As shown in **Figure 21**, mobile operators appear to have a lot of confidence in the ability of testing and performance monitoring tools to accurately assess how successful an upgrade has been. Only 9 percent of respondents hold to the somewhat outdated principle that only the impact of user loading is capable of providing meaningful validation. This aligns well with the 13 percent of respondents in **Figure 20** that dare not believe an upgrade has been successful until the next primary busy hour has been and gone without incident.

Figure 21: Most Important Tools for Validating Successful Completion of an Upgrade

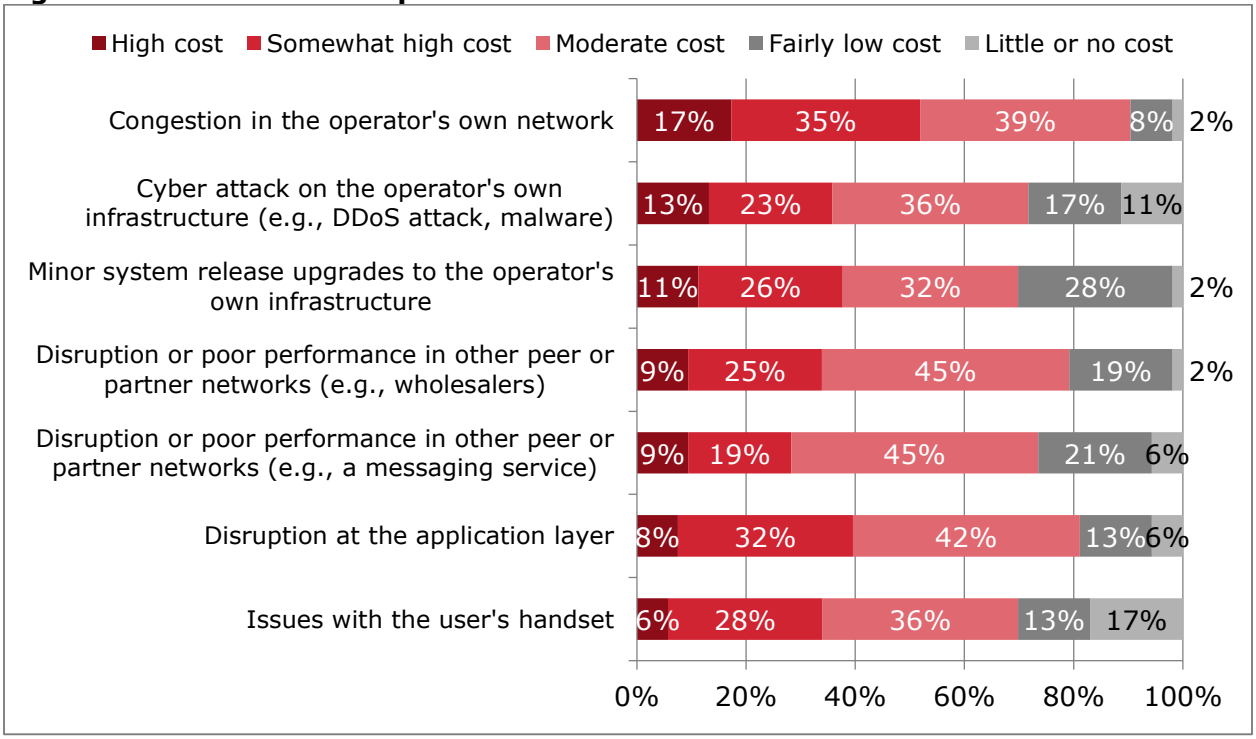


N=54

Visibility in performance monitoring systems and the ability to test in the production network are both highly valued, although performance monitoring systems are rated more highly than the ability to test in the production network. 59 percent of respondents rated performance monitoring systems as the most important factor compared with 32 percent that opted for the ability to test in the production network.

As shown in **Figure 22**, congestion in the operator's own network emerges as the cause of network outages that tends to have the most obvious, measurable, impact on the operator's costs. This is for the simple reason that many incidents arising from congestion tend to drive capex to alleviate the congestion. Just over half of respondents associated congestion with incurring higher costs. It's also noticeable that cyber-attacks feature more prominently now than two years ago, with 36 percent of respondents associating them with higher costs.

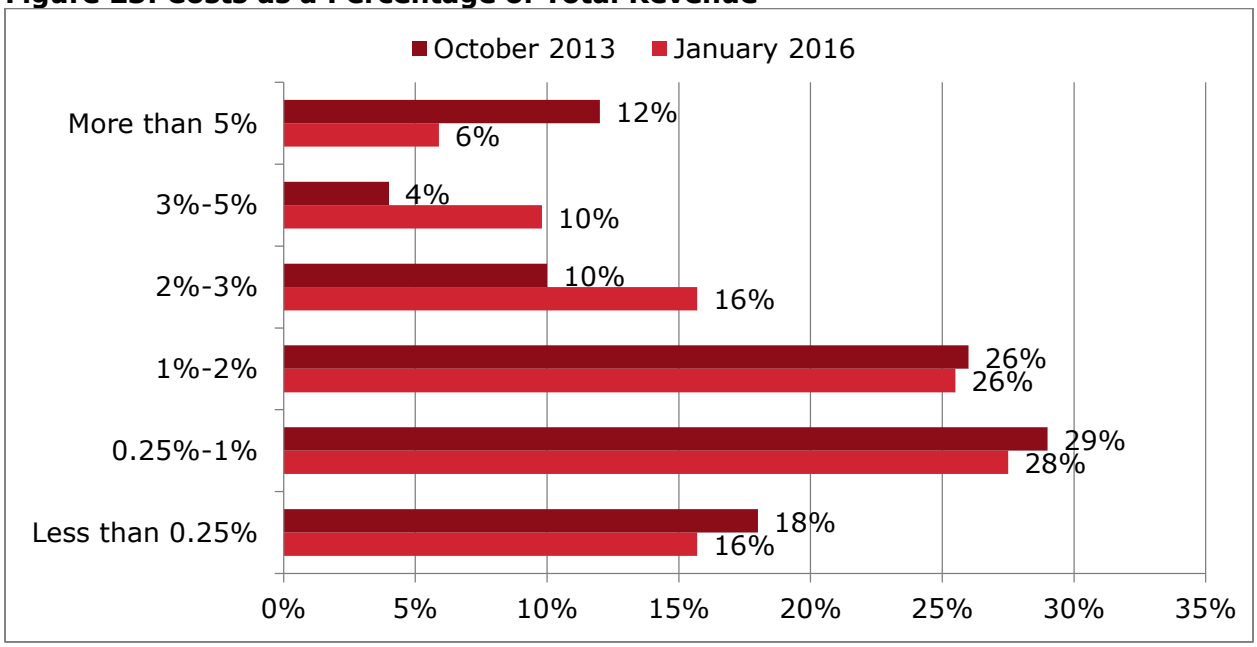
Figure 22: The Relationship Between Cause & Cost



N=54

With mobile service revenues reaching around $1.2 trillion mark in 2015, and survey respondents estimating that their companies spend an average of 1.7% of their revenues on dealing with outages and degradations, **Figure 23** shows that mobile operators now appear to be spending around $20 billion a year dealing with these incidents.

Figure 23: Costs as a Percentage of Total Revenue



N=54

This suggests an 18 percent increase over the $16.9 billion we have re-calculated for 2013 based on our last survey. This 18 percent increase over two years is accounted for by an average of 1.7 percent of annual revenues now estimated by respondents to be being spent on addressing these incidents, up from an average 1.5 percent estimated by respondents two years ago. It is also explained by the $76 billion increase in total annual global mobile service revenues from $1.124 trillion to $1.2 trillion over the last two years.

In our October 2013 survey, we actually concluded that mobile operators were spending $15 billion a year based on a 1.5 percent average (yielded by the survey respondents) share of a rough estimate of a global mobile service market worth $1 trillion. This year we have arrived at our calculation based on the GSM Association's numbers published in its "Mobile Economy 2015" report. This estimates total global mobile services revenues of $1.124 trillion in 2013 rising to $1.2 trillion in 2015.

Using the GSMA's numbers we have therefore normalized the numbers for this report, yielding a revised $16.9 billion figure for 2013 to replace the original $15 billion estimate.

APPENDIX: FULL SURVEY TEXT

What follows is the full text of **Heavy Reading's 2016 Mobile Network Outages & Service Degradations Survey**, conducted in January 2016.

Part 1: Demographic Questions

1. What type of telecom service provider do you work for? [[REQUIRED]]
   - Incumbent telco that has a mobile operating license.
   - Pure-play mobile operator
   - Other [[REJECT]]

2. What is the name of your company?

3. Has your company launched LTE as a live commercial service?
   - Yes
   - No

4. Does your company already offer VoLTE as a live commercial service to customers?
   - Yes
   - No

5. In what region is your organization headquartered?
   - U.S.
   - Canada
   - Central/South America
   - Western Europe
   - Central/Eastern Europe
   - Asia/Pacific
   - Middle East
   - Africa
   - Other (please specify)

6. What is your primary job function?
   - Corporate management
   - Network Planning
   - Network Operations
   - Engineering
   - Sales, & Marketing
   - Service operations
   - Finance
   - Other (please specify)

7. What are your company's approximate annual revenues?

- Less than $50 million
- $50 million to $200 million
- $200 million to $500 million
- $500 million to $1 billion
- $1 billion to $5 billion
- More than $5 billion

Part 2: Trends in Mobile Network Outages, or Service Degradation

The objective of this survey is to understand the impact and implications of both outages and degradations in the mobile network. Throughout the survey, the term "network outages," refers to occasions when the mobile network is down and/or inaccessible or unavailable to users, or when access to specific services, such as internet access for web browsing, are unavailable for a period of time. The term "service degradation," is used to mean occasions when network access to all services or even specific services is severely degraded in a way that impacts the customer experience, so that response times are very slow, all service or specific access is limited or intermittent while other services remain generally accessible.

8. About how many times a year does your company's mobile network suffer from a network outage or service degradation?

- More than 20 times a year
- 15-20 times a year
- 10-15 times a year
- 5-10 times a year
- 3-5 times a year
- 1-3 times a year
- Never

9. Which of the following is the most common problem affecting your mobile subscribers?

- Network outage (all services are down)
- Service outage (one specific service is down)
- Network degradation (all services are experiencing quality problems)
- Service degradation (one specific service is experience quality problems)

10. How has the number of outages and degradations on your mobile network changed over the past two years?

- They have gone up significantly
- They have gone up slightly
- They have stayed about the same
- They have gone down slightly
- They have gone down significantly

11. Please indicate how frequently mobile users experience an outage, or degradation of the following duration [Options: Never, Rarely, Often]

- More than 48 hours
- 24-48 hours
- 4-24 hours
- 2-4 hours
- 1-2 hours
- 30 minutes to 1 hour
- 15-30 minutes
- Less than 15 minutes

12. What trends are you seeing as regards **how often** outages, or degradations have been impacting the mobile network over the last year or two?

- It's happening a lot more often
- It's happening more often
- It's happening as often as it was two years ago
- It's happening less often
- It's happening a lot less often

13. What is the most common impact of outages and degradations that affect your company's mobile networks and services? [Options: Outages, Degradations]

- All networks and services are affected
- Some networks and services are affected but not all
- Only one type of network or service is affected

Part 3: Causes & Remediation

14. How would you rate your company's ability to identify and understand the exact cause of outages and degradations that affect mobile subscribers?

- Excellent
- Good
- Fair
- Inadequate
- Terrible
- Don't know

15. How often are each of the following network – impacting events a contributory factor in causing network outages or service degradations? [Options: Never, Rarely, Often]

- Busy-hour congestion
- A public event (e.g., sports or entertainments event at a stadium)
- A natural disaster (flood, earthquake, tornado)

- A network upgrade
- The launch of a new service
- The launch of a new phone
- The launch of a new tariff or service plan

16. What are the two most frequent causes of network outages affecting your company's mobile networks?

- Network failures
- Physical link failures
- Customer end device issues
- Network congestion/overload
- Network/service enablers
- Application/server issues
- Cybersecurity related attack
- Malicious damage
- Configuration issues

17. What are the two most frequent causes of service degradation affecting your company's mobile networks?

- Network failures
- Physical link failures
- Customer end device issues
- Network congestion/overload
- Network/service enablers
- Application/server issues
- Cybersecurity related attack
- Malicious damage
- Configuration issues

18. What two causes of network outages and service degradation have the most severe impact on your company's mobile networks?

- Network failures
- Physical link failures
- Customer end device issues
- Network congestion/overload
- Network/service enablers
- Application/server issues
- Cybersecurity related attack
- Malicious damage
- Configuration issues

19. Where in your company's mobile networks are outages and service degradations most likely to occur?

- The radio access network (RAN)
- Mobile core – voice (MSC)
- Mobile core – data (GGSN, SGSN, P-GW, SGW)
- SMS infrastructure
- IMS/VoLTE core
- WiFi (ePDG)
- Routing network
- Transport network
- Network enablers (AAA, DNC, HLR, HSS, etc.)
- Data center network or applications
- A partner network
- Access to an application store or service
- Internet access

20. How often are each of the following responsible for degradations in the performance of VoLTE services as experienced by the end user? [Options: Never, Rarely, Often]

- VoLTE client performance in the device
- Performance issues in the IMS/VoLTE service infrastructure itself
- Performance issues in the mobile core
- Performance issues in the backhaul network
- Performance issues in the RAN (on the RF side)

21. How often do network outages or service degradations arise as a result of failures in the following types of relationship with partner network operators [Options: Never, Rarely, Often]

- Internet peering points
- Mobile roaming partners
- Third-party (wholesale) backhaul partners
- Interconnect agreements

22. Please rate the importance to your company of the following mechanisms for becoming aware of outages and degradations affecting your mobile subscribers? [Options: Very important, Somewhat important, Only marginally important, Not important at all]

- Reporting in the general news media or social networking sites
- Customer calls to the customer care center
- Automated notification by network monitoring systems
- We observe service traffic has decreased and deduce there must be an issue
- Notification by other operators
- Notification by cyber security partners

23. How long does it take to upgrade a network event until you are 99% sure that the upgrade has the required functionality and can handle the required capacity of subscribers?

- Within a few minutes of the upgrade being completed
- Within an hour of the upgrade being completed
- Within one to four hours of the upgrade being completed
- Within four to 12 hours
- Not until the primary busy hour in the day has been and gone without incident.

24. What is the most important factor determining your company's ability to be sure that all aspects of a service upgrade have been properly completed?"

- Ability/capacity to test in production network
- Visibility of performance monitoring systems
- Requires user loading to validate
- Other

Part 4: Costs

25. Please rate the annual cost incurred by your company for the following causes of network outages and service degradations. [Options: High cost, Somewhat high cost, Moderate cost, Fairly low cost, Little or no cost]

- Minor system release upgrades to our own infrastructure
- Congestion in our own network
- Cyber-attack on our own infrastructure (e.g., DDoS attack, malware)
- Disruption or poor performance in other peer or partner networks (wholesalers, interconnection partners)
- Disruption or poor performance in other peer or partner networks (e.g., a messaging service)
- Disruption at the application layer
- Issues with the user's handset

26. What percentage of your company's annual mobile revenue is spent on dealing with the impact of network outages and service degradations?

- Less than 0.25%
- Between 0.25% and 1%
- 1%-2%
- 2%-3%
- 3%-5%
- More than 5%