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executive summary 1/2

Telenor contracted Omnitele to benchmark the end-user QoS of voice services in Sweden in Q1/2013

- Scope: Telenor, Telia
- Test execution overview:
  - 100s test call to Nemo Voice Quality Server
  - Measure 2G/3G call success and voice quality
  - Tests done with Nemo Handy (Nokia C7)
- Test campaign was extensive:
  - 79 cities
  - 550 test locations
  - 5 000+ test cases per operator
**Omnitele overall conclusion:** Both operators are equally good meeting industry standards and typical end-user expectations.

**BOTH OPERATORS: VERY HIGH QoS**

- **Total Call Success Rate:** Both very good, no statistically significant difference.
- **Call Setup Time:** Both very good, no perceptible difference from end-user point of view.
- **Voice Quality (MOS):** Voice quality very high for both operators, near practical maximum. No perceptible difference.
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Omnitele in brief

Omnitele was founded in 1988 to set up the first GSM operator and network in the world.

Omnitele has assisted operators in 1,000+ projects in 80+ countries.

Our services range from Technology Strategy to Network Design and Network Quality Improvement for Telecom operations

The headquarter situates in Helsinki, Finland. We have local presence in the Netherlands and the Hashemite Kingdom of Jordan.

The company is owned by Finnish telecom operator groups and is independent of all international operators and telecom equipment vendors.

“Since the beginning of DNA, Omnitele has played a critical role in developing an efficient model for radio network planning and its outsourcing.”

Riitta Tiuraniemi, Managing Director, DNA
Bridging the gap between technology & business

**Technology Strategy**
Evaluating, selecting and managing licenses, technologies and vendors

**Network Design**
Turnkey network planning services for mobile and broadcasting networks

**Network Quality**
Network auditing, optimisation, quality benchmarking and performance management services

“Due to excellent work by Omnitele we achieved our goal to be best in quality”

Dave Newbold
Chief Operations & Technology Officer at JT
1,000+ projects in 80+ countries
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3. **Introduction**
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OBJECTIVE
- To evaluate and benchmark the end-user QoS of voice services in Swedish cellular networks Telenor and Telia

SCOPE COVERAGE
- Measurements in all cities with population > 15,000
- Minimum 2 locations per city, 50 test samples per city, 5 test samples per location
- Locations chosen independently by Omnitele to cover places with high subscriber density (airports, hotels, restaurants, shopping malls, railway/bus terminals, business districts...)
- All together 79 cities, 550 test locations, 5000+ test samples per scenario for each operator

Test Execution
- 100s test call to Nemo Voice Quality Server
- Measure 2G/3G call success and voice quality
- Tests done with Nemo Handy (Nokia C7)
VAST TEST CAMPAIGN
- 79 cities
- 550 locations
- 250+ testing hours
- 10 000+ Voice Calls
- Tests executed Jan 7 – Feb 7

Test Scope in Practice

<table>
<thead>
<tr>
<th>Test Execution</th>
<th>Totals</th>
</tr>
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<tbody>
<tr>
<td>Benchmarked Operators</td>
<td>2</td>
</tr>
<tr>
<td>Number of cities</td>
<td>79</td>
</tr>
<tr>
<td>Number of test locations</td>
<td>550</td>
</tr>
<tr>
<td>Calendar days of testing</td>
<td>31</td>
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<table>
<thead>
<tr>
<th>Voice Aggregates</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice call attempts</td>
<td>10 087</td>
</tr>
<tr>
<td>Voice call hours</td>
<td>279</td>
</tr>
</tbody>
</table>
table of contents

1. Executive summary
2. Omnitele in brief
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6. Annexes
The Nemo Handy is an industry standard test terminal for thorough and advanced measurements on the wireless air interface and mobile application quality-of-service/quality-of-experience QoS/QoE.

More information from www.anite.com

Measurement Script:
1. Call Nemo VQ Server
2. Wait 100 seconds
3. Disconnect Call
4. Wait 10 seconds
5. Go to 1

*Nemo VQ Server located in Telenor premises. Connected to PSTN with E1.
Coherent test procedure strictly followed. Methodology defined to capture true end-user behaviour. Measurements conducted where and when real subscribers are using voice services.

**TESTING TIMES REPRESENT TYPICAL END-USER BEHAVIOUR:**
- **Test days:** Testing only between Monday and Saturday.
- **Test hours:** Testing not conducted during night hours: 00.00 – 06.00
- **Saturdays:** Measurements only between 10:00 – 00:00. No Saturday measurements in business or university areas.
- **Sundays:** No testing on Sundays.

**METHODOLOGY**
- State of the art test equipment used to benchmark best available end-user QoS offered by the operators.
- Locations chosen independently by Omnitele to cover places with high subscriber density (airports, hotels, restaurants, shopping malls, railway/bus terminals, business districts...)
- All tests executed in stationary state inside a car. No mobility testing.
- Measurement devices always in same place, on the car dashboard
- Detailed results saved for each test separately. Failures recorded as well.
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6. Annexes
Key Conclusions: Voice call success performance is very good for both

- No statistically significant difference observed between operators
- Both operators are well aligned with industry standards and end-user expectations
- Telia’s success rate (99.7%) is slightly higher than Telenor’s (99.5%)

Total Call Success Rate

<table>
<thead>
<tr>
<th></th>
<th>Telenor</th>
<th>Telia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call attempts</td>
<td>5048</td>
<td>5039</td>
</tr>
<tr>
<td>Call attempt failures</td>
<td>20</td>
<td>8</td>
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<tr>
<td>Call drops</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total failures</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>Total Call Success Rate</td>
<td>99.54 %</td>
<td>99.74 %</td>
</tr>
<tr>
<td>Confidence Interval</td>
<td>0.2 %</td>
<td>0.1 %</td>
</tr>
<tr>
<td>Compared to Telenor</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Ranking</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

△ Significantly better than Telenor
No statistically significant difference
▼ Significantly worse than Telenor

Total Call Success Rate (TCSR) describes the probability that an end-user can successfully initiate and complete a voice call. It takes into account all call failures in end-to-end fashion: “No coverage”, “Congestion”, “Call Dropped”.

©Omnitele Ltd. 2012
Competitive Network Benchmark for Telenor Sverige AB
BOTH GOOD, NO STATISTICALLY SIGNIFICANT DIFFERENCES

• Call Setup Success Rate: Telia performs better with 99.8%
• Call Completion Rate: Telenor performs better with 99.9%
• Both operators aligned with industry standards and end-user expectations

### Call Setup Success Rate

<table>
<thead>
<tr>
<th>Operator</th>
<th>Percentage</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telenor</td>
<td>99.60%</td>
<td>0.2%</td>
</tr>
<tr>
<td>Telia</td>
<td>99.84%</td>
<td>0.1%</td>
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</tbody>
</table>

**Ranking**

- Telia: 1
- Telenor: 2

#### Call Completion Rate

<table>
<thead>
<tr>
<th>Operator</th>
<th>Percentage</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telenor</td>
<td>99.94%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Telia</td>
<td>99.90%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

**Ranking**

- Telia: 1
- Telenor: 2

▲ Significantly better than Telenor
- No statistically significant difference
▼ Significantly worse than Telenor
 BOTH GOOD, NO PRACTICAL DIFFERENCES

- Both operators perform well, exceeding industry standards and end-user expectations
- Telenor performs slightly better, but there might be some biasing from VQ server location. (Server in Telenor premises)
- No perceptible difference from end-user point of view

Call Setup Time (CST) is the time between end-user’s call setup request and called party answer. Values below 5 seconds can be considered satisfactory from end-user perspective.
Call Setup Time Cumulative Distribution

- Telenor
- Telia

Voice | Call Setup Time

Call Setup Time Cumulative Distribution

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Seconds
Voice Quality is assessed with MOS (Mean Opinion Score). MOS is expressed as a single number in the range 1 to 5, where 1 is lowest perceived audio quality, and 5 is the highest perceived audio quality measurement.

**BOTH GOOD, NO PERCEPTIBLE DIFFERENCE**

- Although statistically significant differences exist, the end-user experience is practically same for both operators.
- Telenor performs slightly better with a MOS value 3.8

<table>
<thead>
<tr>
<th>MOS</th>
<th>Quality</th>
<th>Impairment</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Excellent</td>
<td>Imperceptible</td>
</tr>
<tr>
<td>4</td>
<td>Good</td>
<td>Perceptible but not annoying</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
<td>Slightly Annoying</td>
</tr>
<tr>
<td>2</td>
<td>Poor</td>
<td>Annoying</td>
</tr>
<tr>
<td>1</td>
<td>Bad</td>
<td>Very Annoying</td>
</tr>
</tbody>
</table>

Average Voice Quality MOS

- **Telenor**
  - Average: 3.77
  - Min: 0.00
  - Max: 3.98
  - Standard deviation: 0.18
  - Standard error: 0.008
  - Isolated Measurements: 542
  - Confidence Interval: 0.02
  - Difference to Telenor: 0.07
  - Ranking: 1

- **Telia**
  - Average: 3.70
  - Min: 0.00
  - Max: 3.97
  - Standard deviation: 0.43
  - Standard error: 0.018
  - Isolated Measurements: 549
  - Confidence Interval: 0.04
  - Difference to Telenor: 0.07
  - Ranking: 2
Voice Quality MOS Cumulative Distribution

- **Telenor**
- **Telia**

Voice Quality MOS Cumulative Distribution: ©Omnitele Ltd. 2012
List of Annexes
1. Key Performance Indicators, Voice
2. Confidence interval calculation
3. 79 cities, 550 locations
### Key Performance Indicators, Voice

<table>
<thead>
<tr>
<th>KPI</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Call Setup Success Rate</td>
<td>Definition according to ETSI TS 102 250-2: The probability that an end-user can successfully setup a circuit switched voice call. Formula: #Successful_Call_setups / #Call_Attempts Criteria of successful call setup: Called party answered Pre-conditions: No preconditions. Call attempt recorded even if no radio coverage in place and service not available.</td>
<td>%</td>
</tr>
<tr>
<td>Call Completion Rate</td>
<td>Definition according to ETSI TS 102 250-2: Probability that a successful call attempt is maintained for a predetermined time until it is released intentionally by A- or B-party. Call completion rate [%] = #Intentionally_terminated_calls / #successful_call_attempts Criteria of successfully completed call: User releases the call</td>
<td>%</td>
</tr>
<tr>
<td>Total Call Success Rate</td>
<td>The overall probability that an end-user can successfully setup and complete a circuit switched voice call taking into account all possible call failures in end-to-end fashion. Formula: Call_Setup_Success_Rate * Call_Completion_Rate = [#Call_Attempts - #Call_Attempt.Failures - #Call_Drops] / [#Call_Attempts]</td>
<td>%</td>
</tr>
<tr>
<td>Average Call SETUP Time</td>
<td>Definition according to ETSI TS 102 250-2: Setup Time Telephony (ST-T). Time between sending of complete address information and receipt of call set-up notification. Formula: Voice call setup time = t2 - t1. t1: point of time where the customer presses the send button on mobile equipment (command for call establishment is sent from test SW) t2: point of time where connect is established (called party answered). Average value per location counted as: UM[Call_Setup_Time] / COUNT[Call_Setup_Time]</td>
<td>s</td>
</tr>
<tr>
<td>Voice Quality MOS</td>
<td>Definition according to ETSI TS 102 250-2: Speech Quality on Call basis (SpQ-C). Indicator representing the quantification of the end-to-end speech transmission quality of the Mobile Telephony Service. This parameter computes the speech quality on the basis of completed calls. That is, for each completed call, average downlink MOS scale speech quality value is calculated. The MOS is expressed as a single number in the range 1 to 5, where 1 is lowest perceived audio quality, and 5 is the highest perceived audio quality measurement. The applied MOS algorithm: Psytechnics PSM Mobile, compatible with ITU P.563 standard. Average value per location counted as: SUM[MOS] / COUNT[MOS]</td>
<td>1-5</td>
</tr>
</tbody>
</table>
RATIONAL

In order to analyse the statistical reliability of the results, Omnitele applies confidence interval analysis on the calculated KPIs. Confidence Interval can be considered as the error margin of the reported results. The error margins are visible in the graphs of this report in the error bars, see example figure below. In case two competing operators have differing mean values, but overlapping error bars, the observed difference in average value is not statistically significant. If the error bars don’t overlap, the difference is statistically significant.

CALCULATION

The calculated confidence interval $CI$ is based on (two-tailed) confidence level of 95%. That is, with 95% probability the true population mean is within the sample mean +/- $CI$.

The $CI$ is calculated as $1.96 \times SE$, where
- $SE$ is equal to the standard error for the sample mean, and
- 1.96 is the .975 quantile of the normal distribution ($CL = 0.95 \Rightarrow \alpha = 0.05 \Rightarrow 1 - \alpha/2 = 0.975$, Norm.Inv[0.975] = 1.96)

Standard Error $SE$ of the sample mean, is defined as $s / \sqrt{n}$, where
- $s$ is the sample standard deviation (i.e., the sample-based estimate of the standard deviation of the population), and
- $n$ is the size (number of observations) of the sample.
annexes  |  79 cities, 550 locations

<table>
<thead>
<tr>
<th>City</th>
<th>Locations</th>
<th>Tests/OP</th>
<th>City</th>
<th>Locations</th>
<th>Tests/OP</th>
<th>City</th>
<th>Locations</th>
<th>Tests/OP</th>
</tr>
</thead>
<tbody>
<tr>
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<td>51</td>
<td>Kiruna</td>
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<td>Piteå</td>
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<td>Kristinehamns</td>
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</table>

**Aggregates**
- Total Towns/Cities: 79
- Total test locations: 550
- Total tests/operator/scenario: 5067
Want to know more?

Visit [www.omnitele.com](http://www.omnitele.com) for news, references, and events and check out our blog for the latest Omnitele information:

- Read our Blog
- Find out about events
- Check the latest news
- View customer references
- Read market commentaries