ACQUA – Estimate the quality of applications at the Internet access

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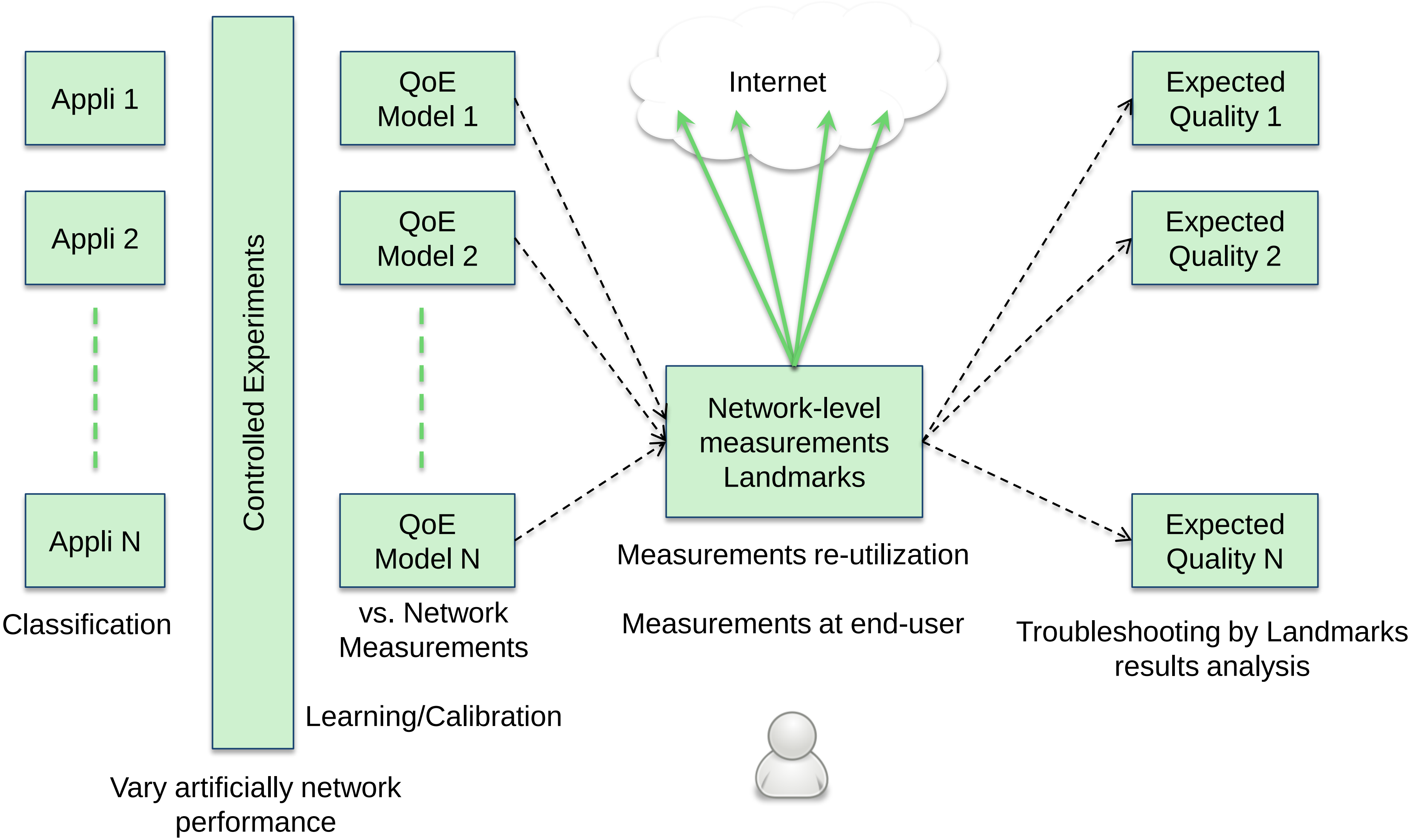
ACQUA in a nutshell

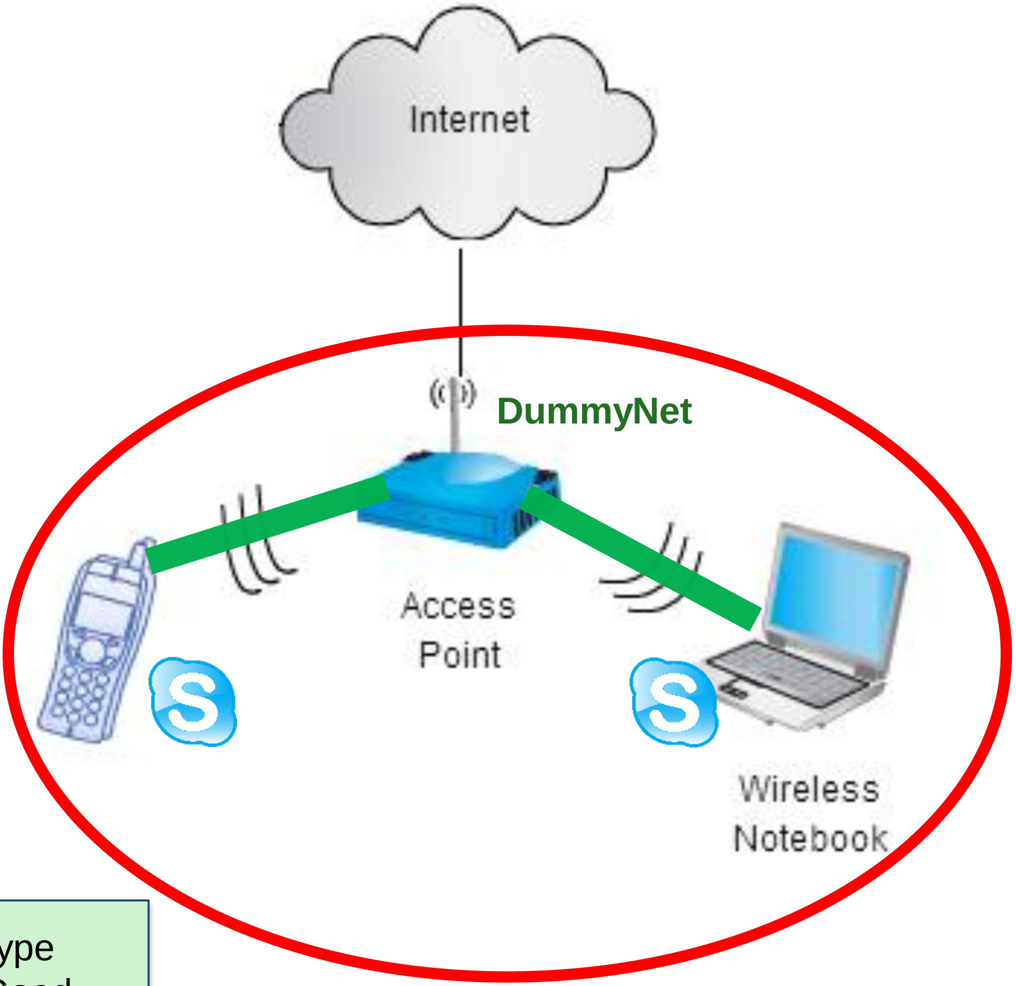
- A new framework for Quality of Experience estimation/prediction starting from network-level measurements and specified to applications
  - "Weather forecasts" of Internet access at the application level
- New models to map directly QoE to network-level measurements
  - First calibration of models in the lab, then crowd sourcing for refinement
- To answer questions as:
  - Should my skype work? How well?
  - Does it have sense to call someone now? Or shall I wait?
  - Should my video streaming work? How well?
  - Access profiling
  - QoE-based troubleshooting
  - QoE-based mobility

ACQUA in a nutshell



The Skype use case

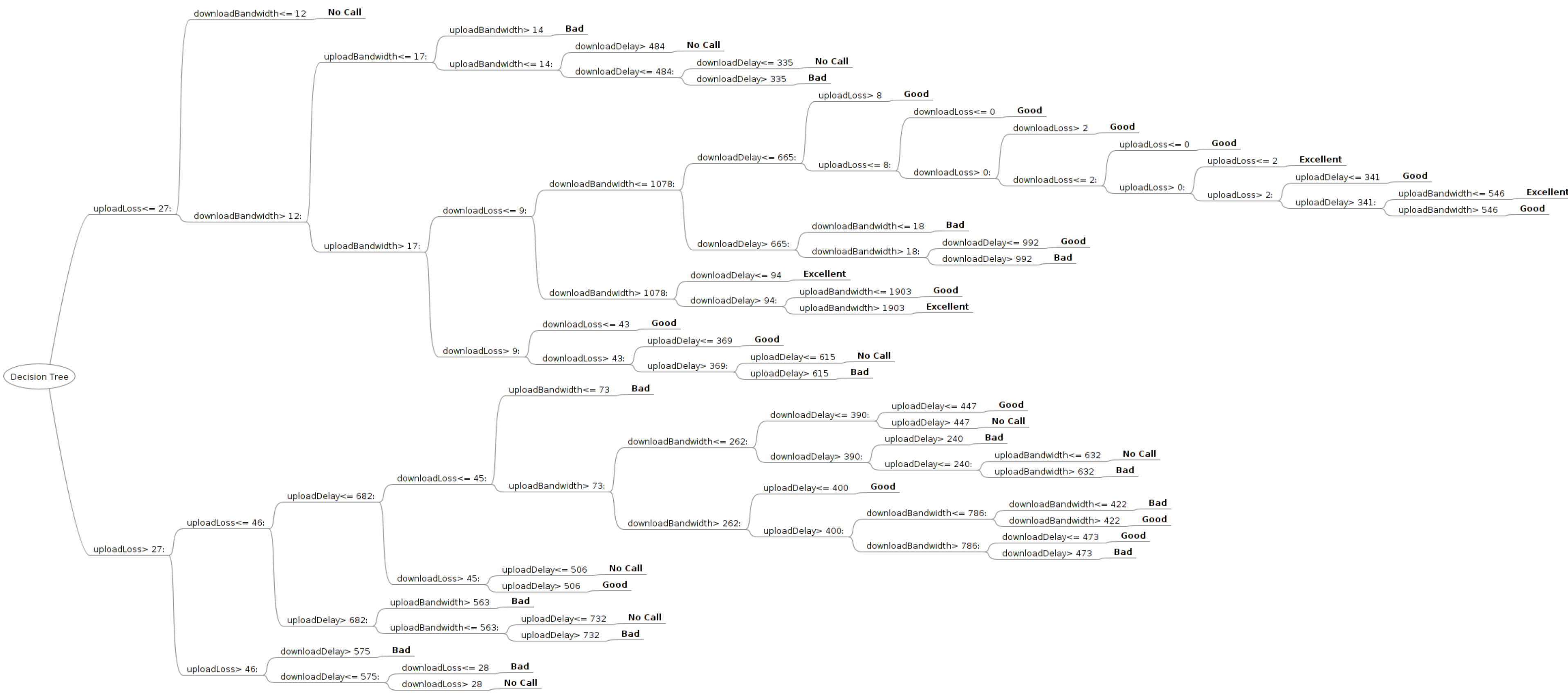
- Six network path metrics:
  - Bandwidth, delay and loss
  - Both upload and download
- QoE = Skype quality meter
- Controlled experimental setup
  - DummyNet at access point
  - Both ways
  - Local Skype traffic
  - Quality vs. conditions



One experiment

One configuration (6 values)	→	QoE of Skype (Excellent, Good, Bad, No Call)

Skype QoE model as a binary tree



Skype QoE model as a set of rules

- Rule = set of branches from root to leaf
- 20 rules (after pruning)
  - **Rule 1:** Download Bandwidth > 1078, Download Delay <= 94 → class “Excellent” [84.1%]
  - **Rule 2:** Upd Bandwidth > 1903, Dwn Bandwidth > 1078 → class “Excellent” [70.7%]
  - **Rule 3:** Dwn Bandwidth <= 1078, Dwn Delay <= 665, Upd Loss > 0, Upd Loss <= 2, Dwn Loss > 0, Dwn Loss <= 2 → class “Excellent” [66.2%]
  - **Rule 4:** Dwn Bandwidth <= 12 → class “No Call” [90.6%]
  - **Rule 5:** Upd Bandwidth <= 14, Upd Loss <= 27 → class “No Call” [75.7%]
  - **Rule 6:** Upd Delay <= 506, Upd Loss > 27, Upd Loss <= 46, Dwn Loss > 45 → class “No Call” [61.2%]
  -
  -
  -
  - **Default class:** Good

ARQ/FEC

12kbs
a critical rate

Skype can easily deal with
one-way losses if bandwidth is available
one-way delay up tp 400ms

Thank you

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http://planete.inria.fr/acqua/

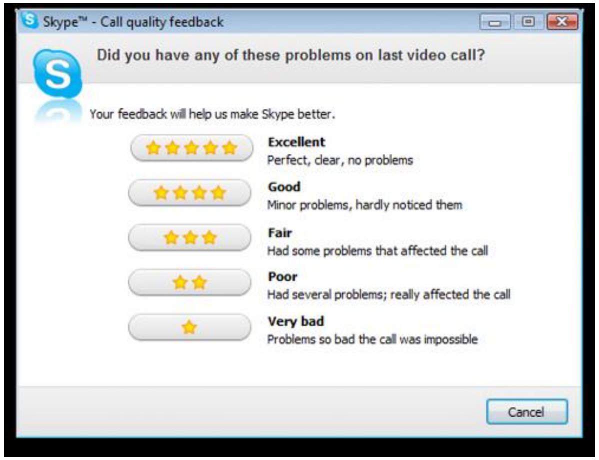
Context

- Quality of Internet access (Ethernet, ADSL, Mobile, Wifi, etc)
- Variety of measurements tools (bandwidth, delay, loss, topology, etc)
  - Network-level measurements
  - Very useful information, but requires knowledgeable people
  - Does not suit the new usage of the Internet centered around applications and services
- What about knowing more on the access performance?
  - Quality of applications (audio, streaming, etc)
  - Ex. Does/Should my streaming work? How well?

    Does it have a sense to call someone now? Or shall I wait?
  - Quality of Experience (QoE) vs. Quality of Service (QoS)
  - Access profiling in terms of QoE, in addition to QoS ….

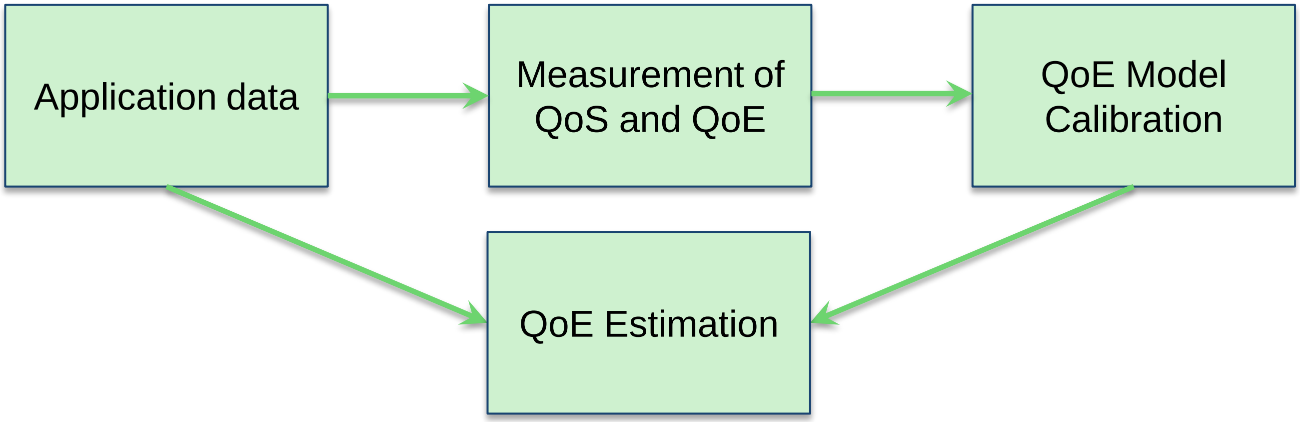
Some background on QoE

- Subjective measurement (human perception)
- MOS: Mean Opinion Score
  - Have people live the experience and give a mark
  - Quality of an audio and video encoding for example
- In networking we need more: QoE vs. QoS
  - Have people live the experience and give a mark (Lab or Crowdsourcing)
  - Measure corresponding QoS
  - Build a model linking QoE to QoS: machine learning, neural networks, etc
  - Ex. Skype quality meter



QoE vs. QoS: Inband vs outband measurements

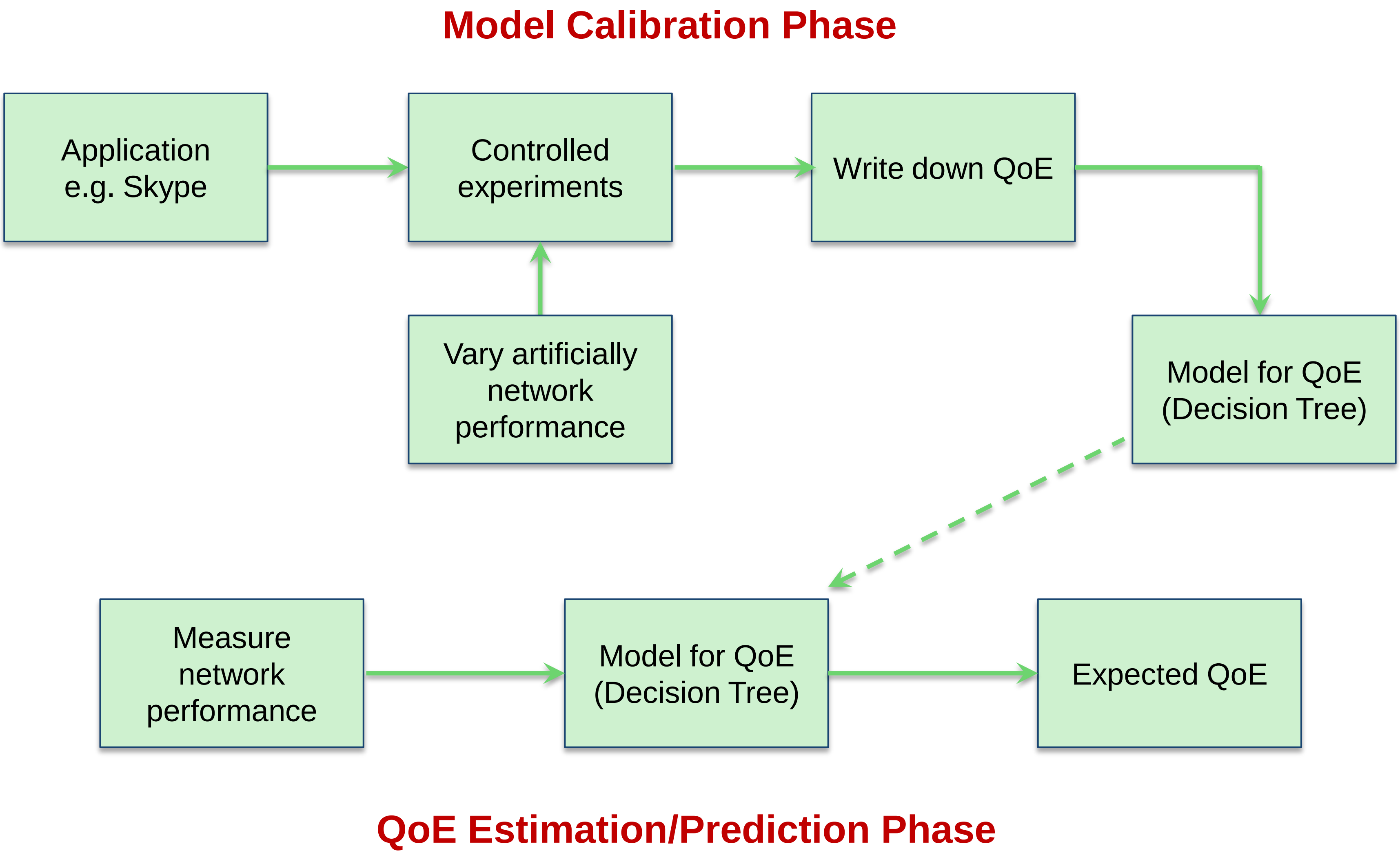
- **Inband QoS measurements (state of the art, ex. Skype, browser plugin)**



- **Outband QoS measurements: ACQUA**

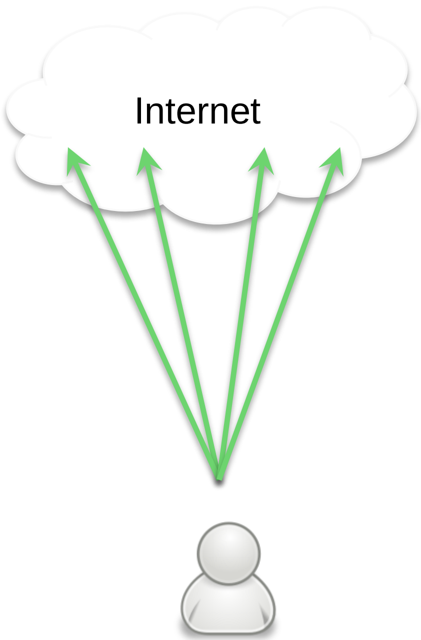
  - QoE prediction outside the modelled application (no need to run the application)
  - New models are required to map directly QoE to network-level measurements

QoE vs. QoS in ACQUA



Network measurements in ACQUA

- Path-level metrics (bandwidth, delay and loss, upload and download)
- Measurement re-utilization among different application models
- **Landmarks**
  - Measurement servers
  - Aggregate observations to estimate metrics as:
    - Mean performance, Variance, Quantile
    - Expected QoE per server
  - Troubleshooting:
    - Percentage of low-quality paths (ITC paper)
    - Localization by elimination
  - A dozen of landmarks give satisfactory results



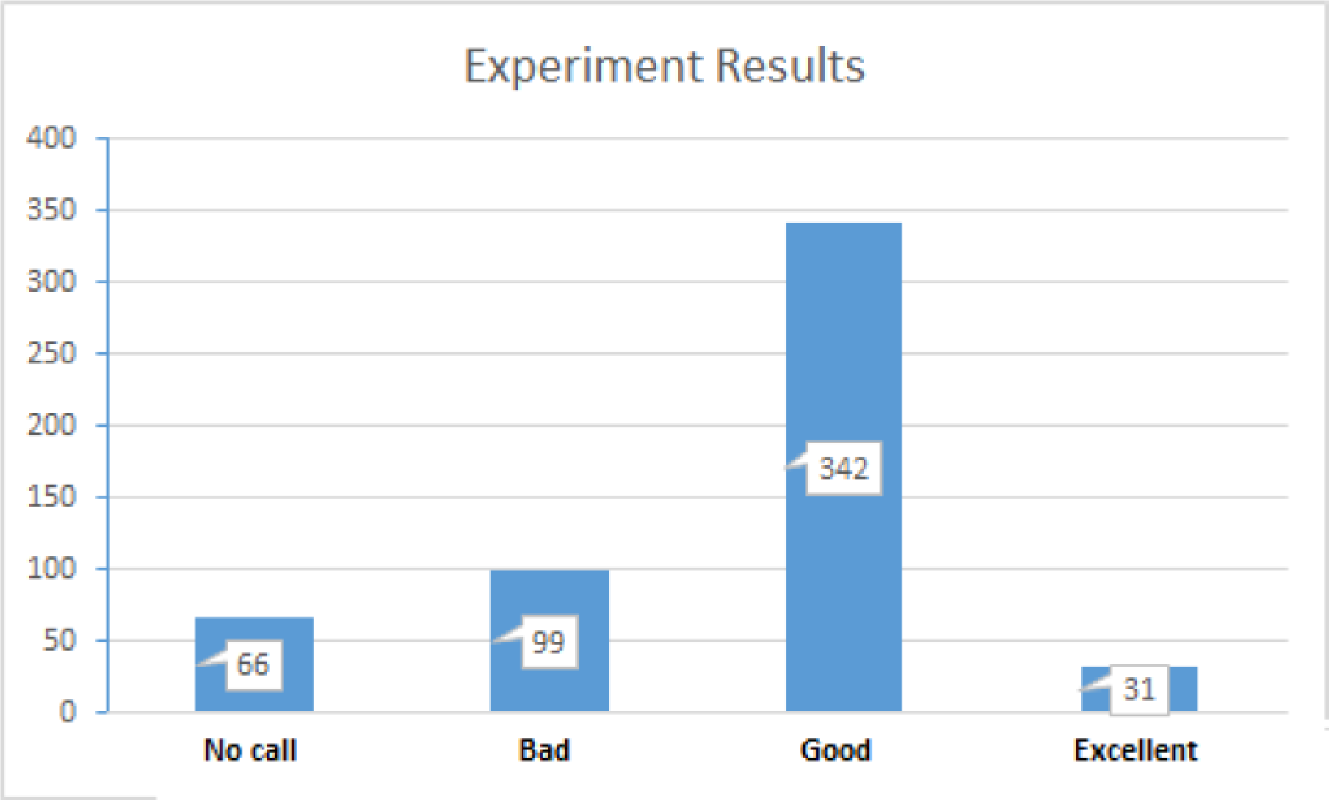
Sampling the space of parameters

- Fair coverage of the six-dimensional space
  - With random selection, the probability to pick a corner is as low as 10^{-6} !
- FAST: Fourier Amplitude Sensitivity Analysis
  - Virtual time
  - Each parameter is a sinusoid of virtual time, with different frequency
  - FAST provides sensitivity analysis for free
    - Energy of a parameter = Energy of the corresponding frequency in the output spectrum + its replicas
  - 538 experiments with repetitions

Download Bandwidth: [1-1000] kbps
Upload Bandwidth: [1-1000] kbps
Download Loss: [1-50] %
Upload Loss: [1-50] %
Download Delay: [1-1000] ms
Upload Delay: [1-1000] ms

Download Bandwidth	Upload Bandwidth	Download Delay	Upload Delay	Download Loss	Upload Loss	QoE RESULT
1024 kbps	850 kbps	36ms	39 ms	1 %	0 %	Excellent
550 kbps	400 kbps	136ms	130 ms	2 %	1 %	Good
220 kbps	180 kbps	77ms	77 ms	5 %	3 %	Good
80 kbps	150 kbps	120ms	125 ms	10 %	5 %	Bad

Frequency of quality results



Decision Tree Building

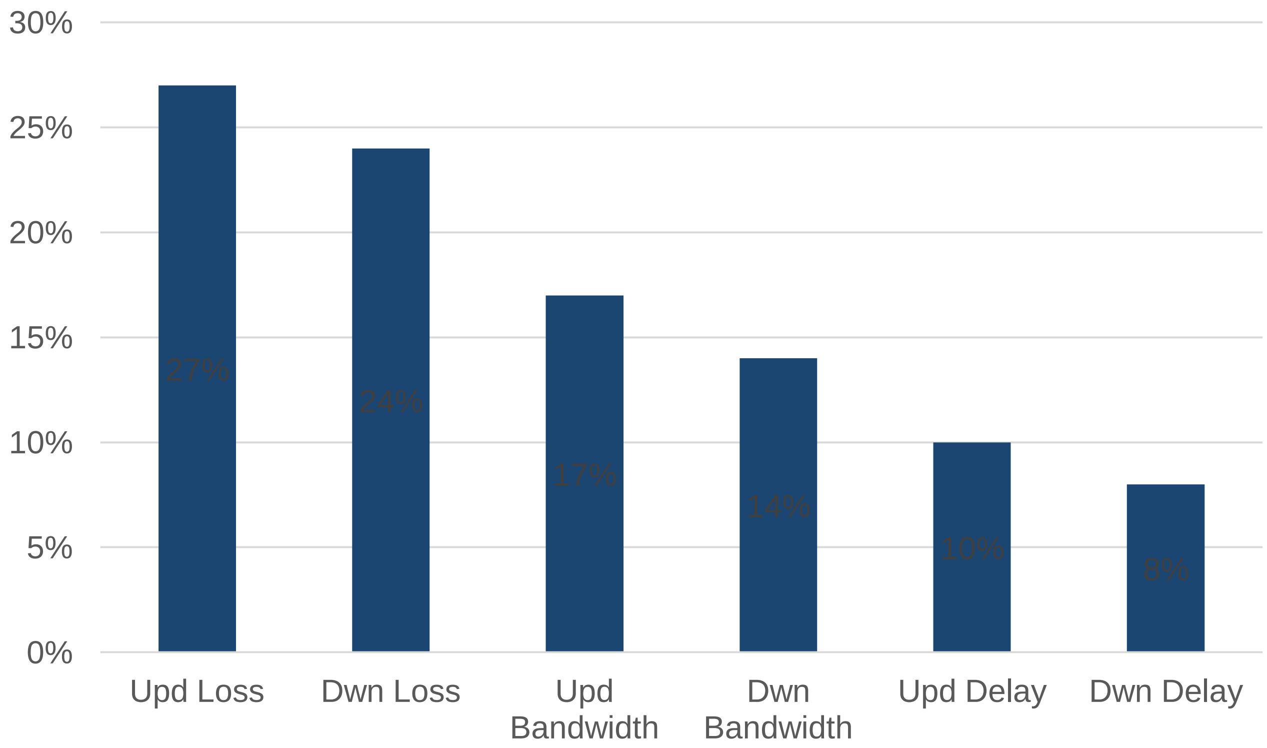
- Chosen for its efficiency, readability and ease of implementation
- C4.5 algorithm:
  - Numerical attributes and tree pruning
  - Top down tree building
  - Start with attributes providing the maximum information gain

    (best compression of the tree if attribute removed)
  - Pruning: remove low frequency leafs

	Before Pruning	After Pruning
Size of Tree	99 nodes	73 nodes
Classification accuracy	85.7%	83.5%

Sensitivity analysis (FAST)

- Participation of each metric to the overall variability of the quality

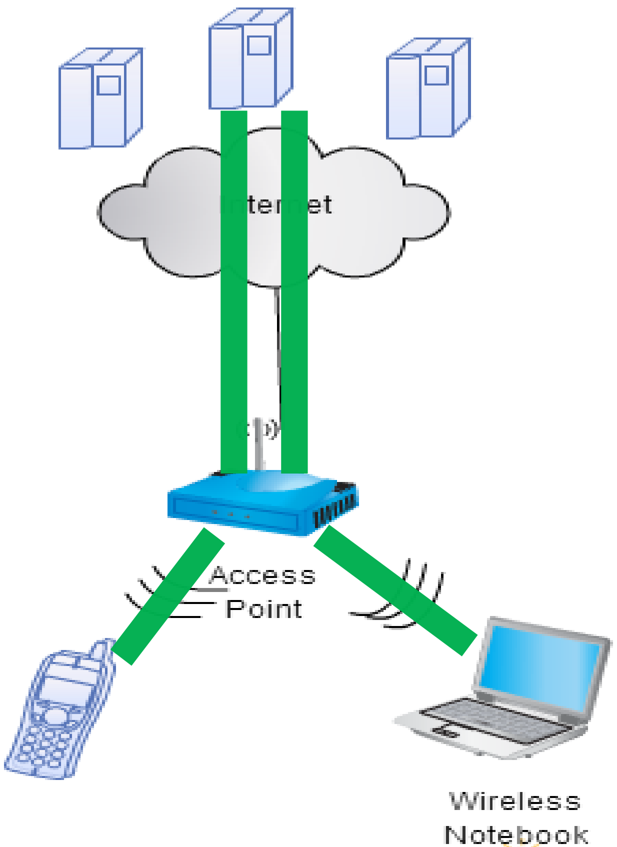


PlanetLab experiments

- Dummynet is finally not reality
  - Real paths different than emulated ones
  - Metrics unknowns, to be measured
- PlanetLab-driven path conditions
  - Tunneling via PlanetLab instead of emulation
  - Running measurement tools
  - Almost same accuracy as in the lab

Node	Upd Band	Dwn Band	Upd Delay	Dwn Delay	Upd Loss	Dwn Loss	Exp QoE	Real QoE
France	7,818	734	29	29	0	0	Good	Excellent
Argentine	7,644	7,801	249	249	0	0	Excellent	Excellent
Belgium	7,483	7,583	42	45	0	0	Excellent	Excellent
England	14,666	2,305	1	1	0	0	Excellent	Excellent
Russia	1,805	4,090	182	184	0	0	Excellent	Excellent
Sweden	20,106	9,051	46	47	0	0	Excellent	Excellent
Australia	5,531	5,725	393	390	0	5	Excellent	Excellent
China	662	435	205	207	4	6	Bad	Bad
Korea	3,981	3,142	296	296	3	2	Excellent	Good
USA	1,709	10,436	147	147	0	0	Excellent	Excellent
India	1,500	750	190	192	2	3	Good	Good

PlanetLab nodes



Concluding remarks

- A new framework for QoE estimation/prediction starting from network-level measurements
- Methodology to be applied to other applications as well
  - Meters might not be present
- First calibration of models in the lab, then crowd sourcing for refinement
- Measurements themselves pose lot of problems:
  - How to perform them to reflect application traffic pattern?
  - Choice of measurement servers
  - Overhead of measurements
    - Collaboration of users and network
  - Tracking dynamicity of paths