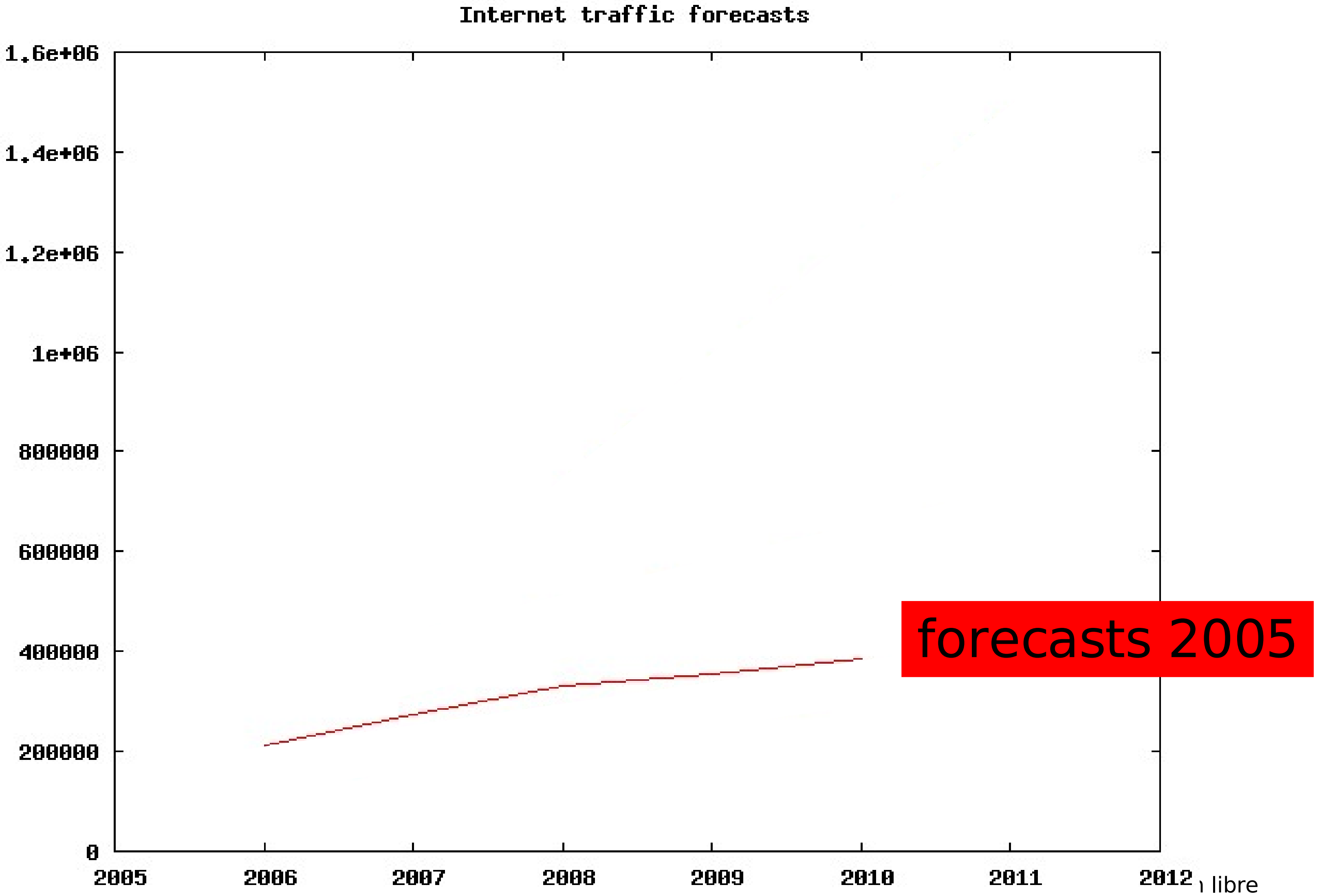
Access network dimensioning with uncertain traffic forecasts

Orange Labs

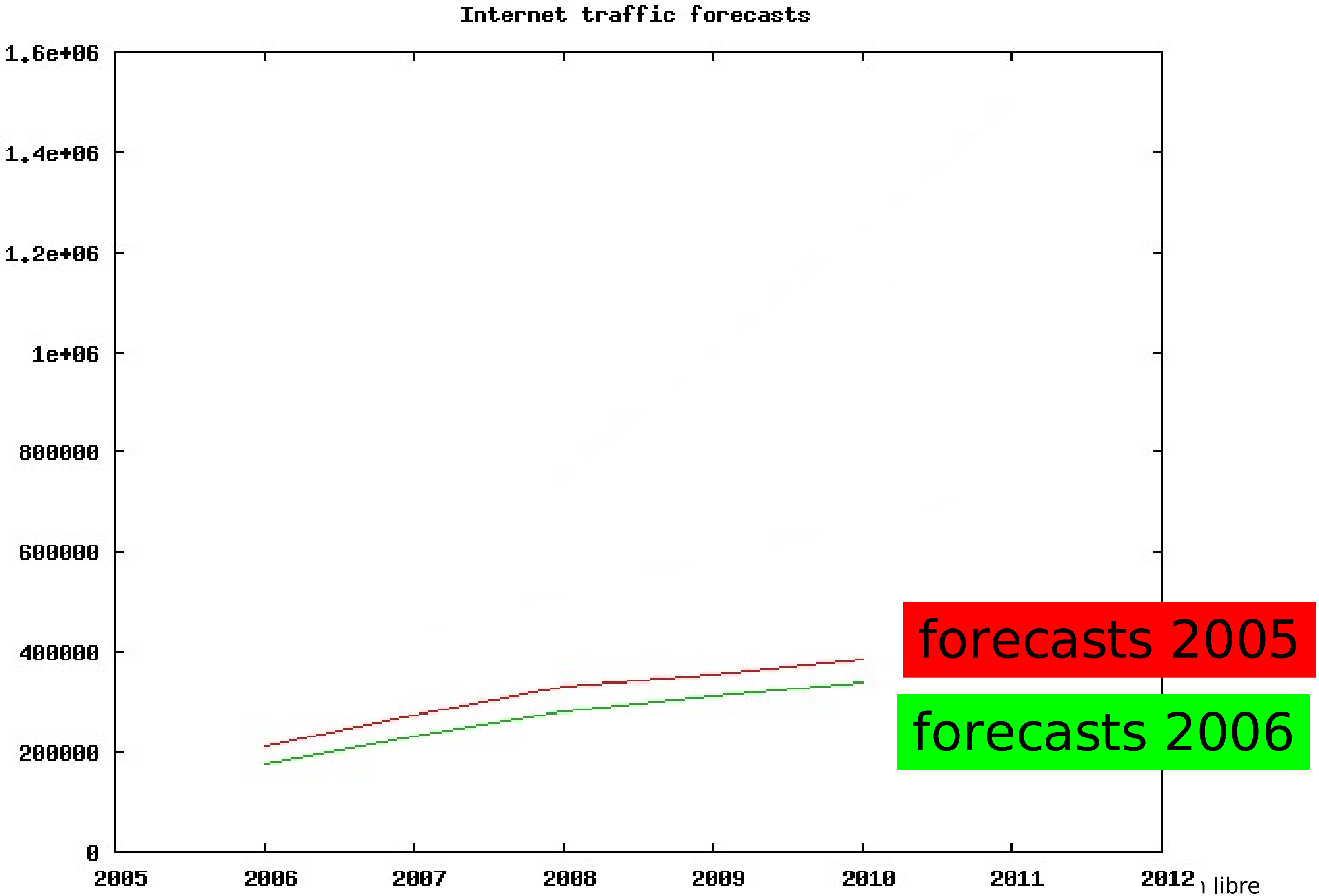
Olivier Klopfenstein, Research & Development
Networks 2008, Budapest

outline

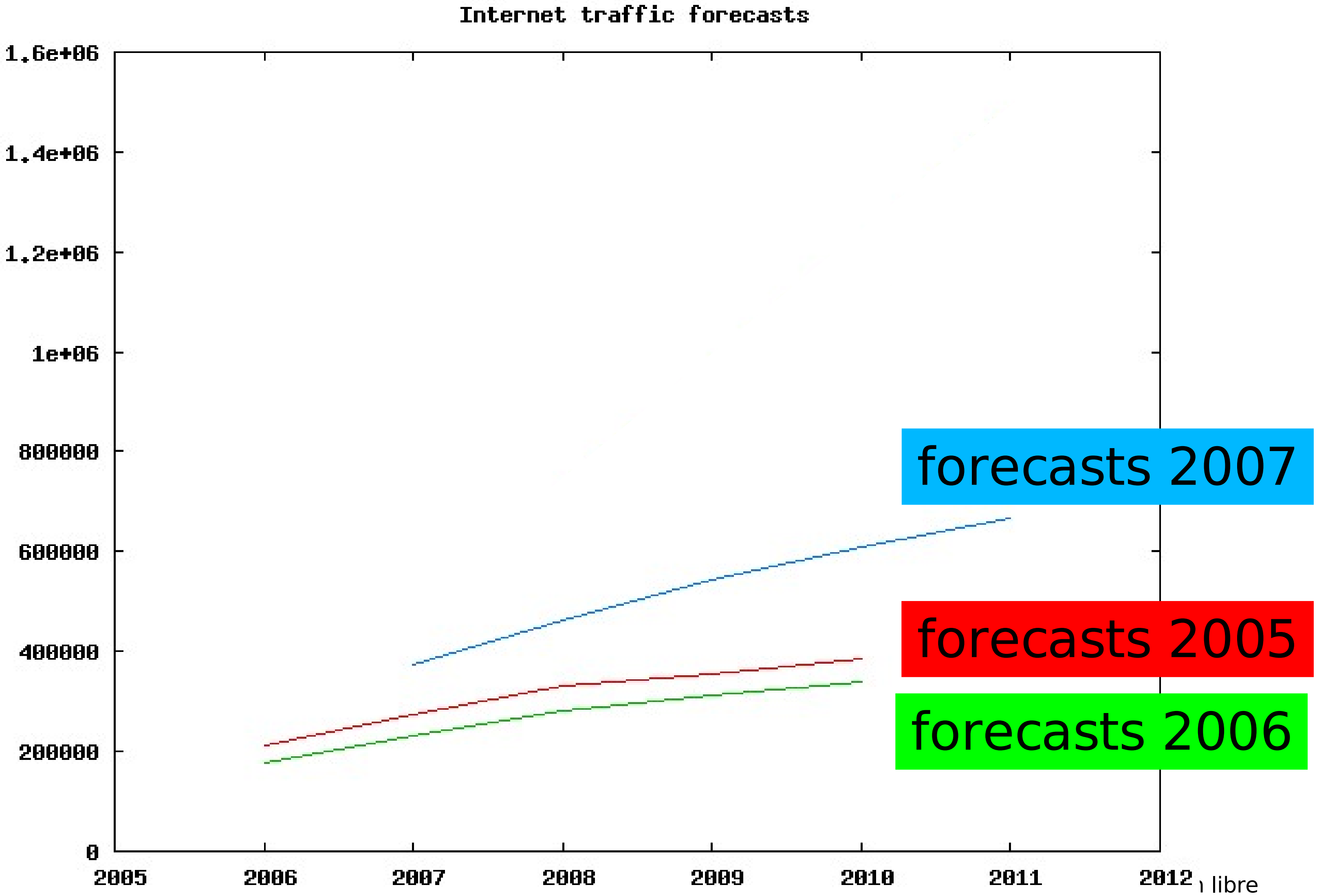
the hard work of forecasting...



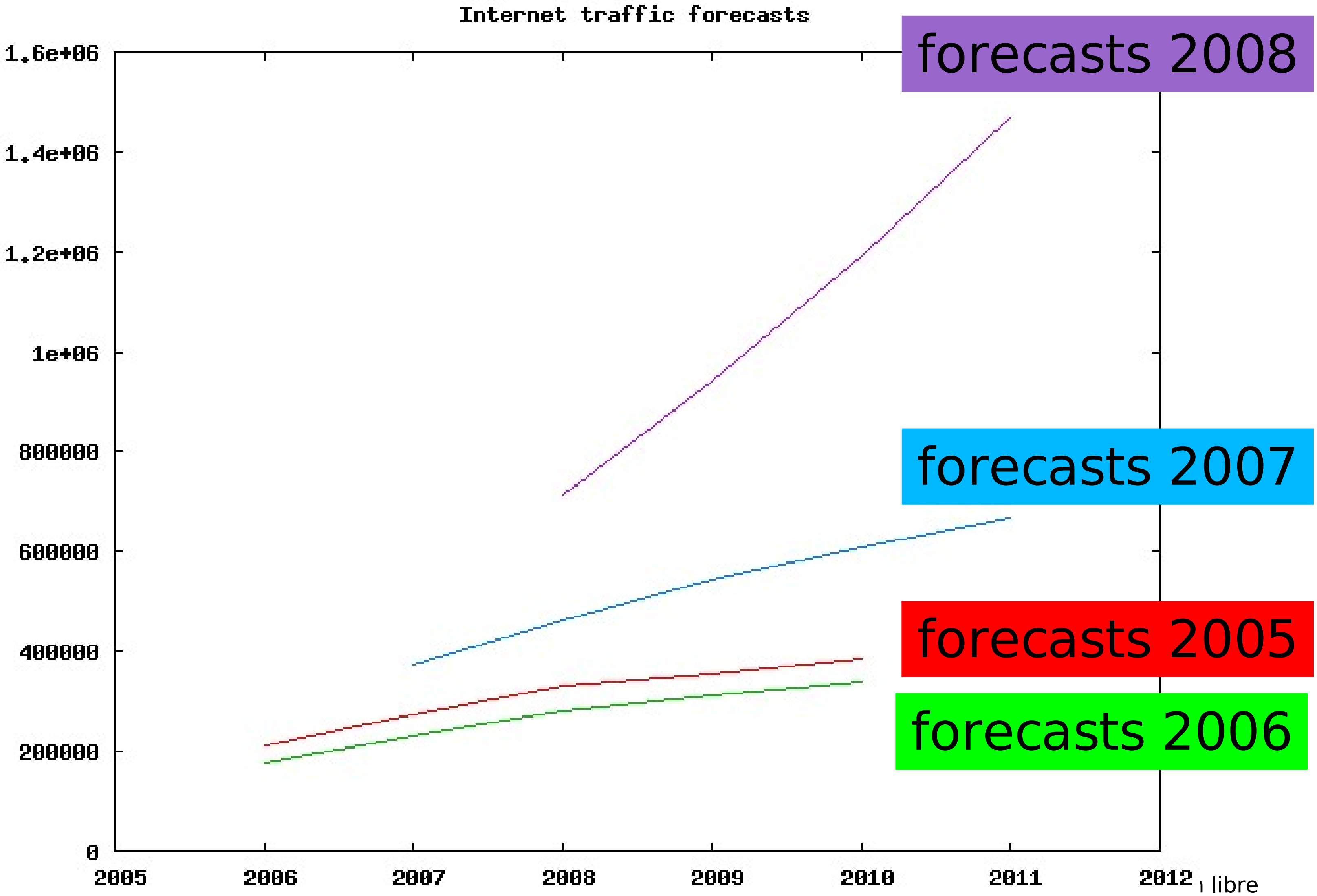
the hard work of forecasting...



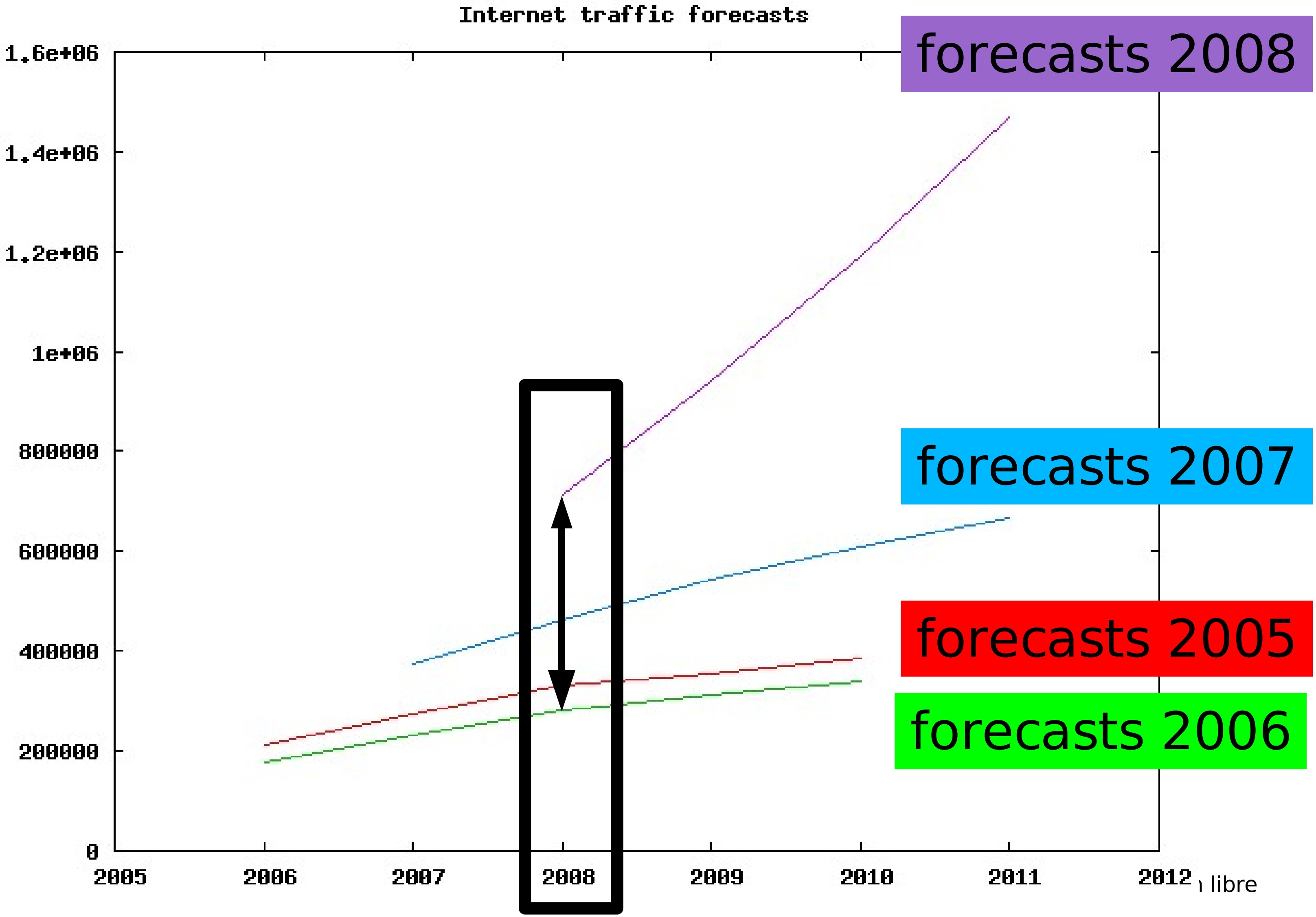
the hard work of forecasting...



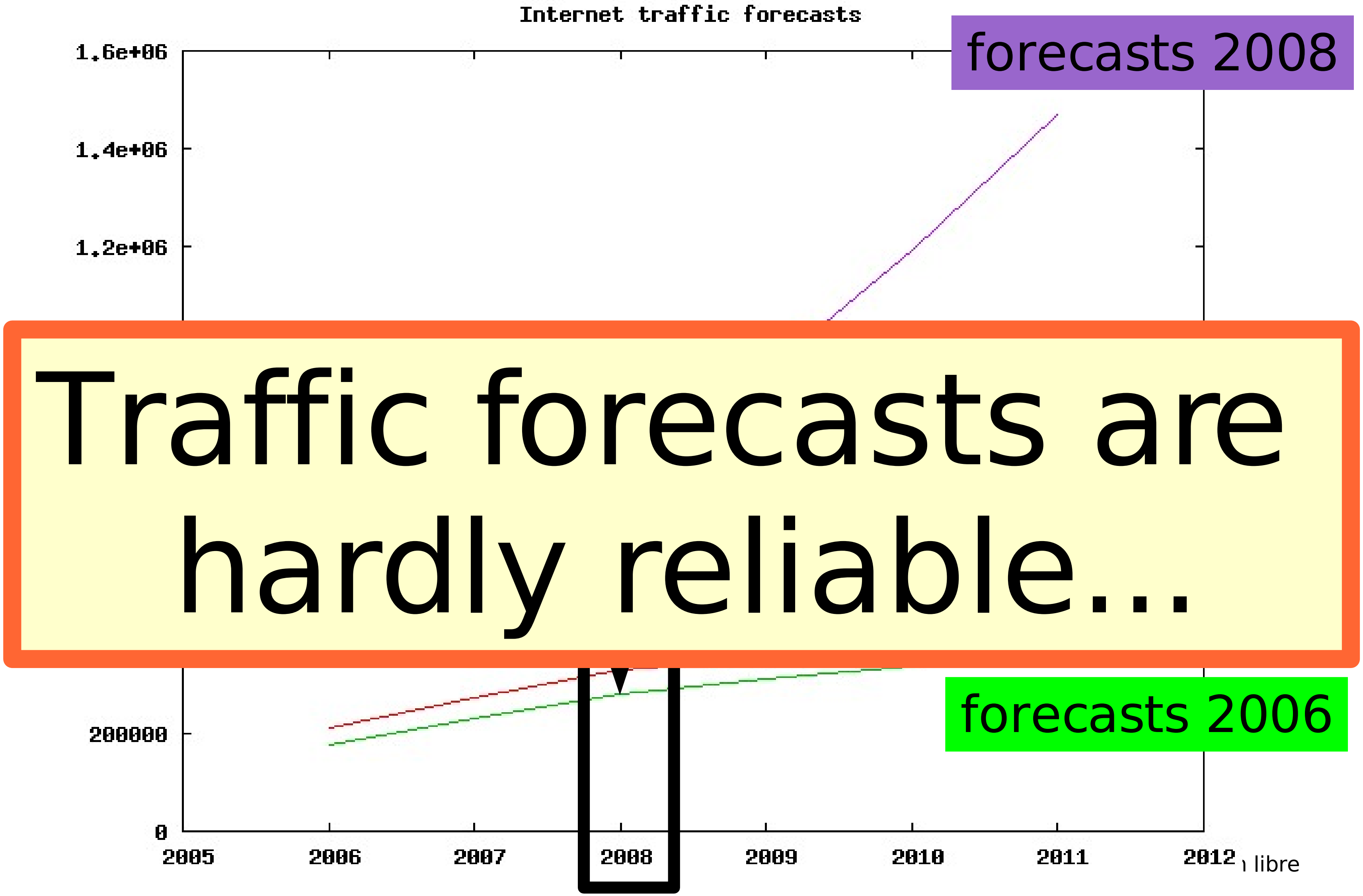
the hard work of forecasting...



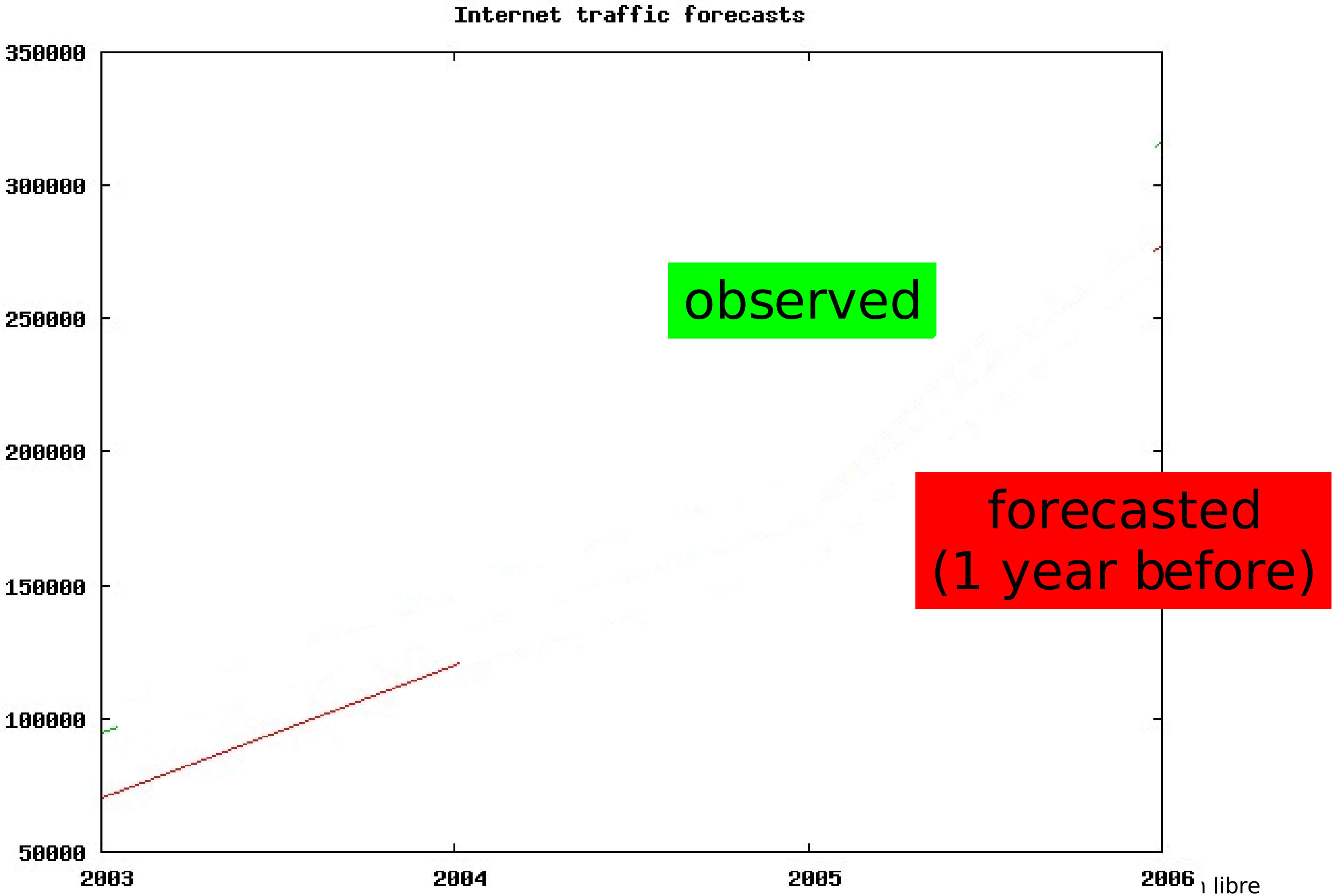
the hard work of forecasting...



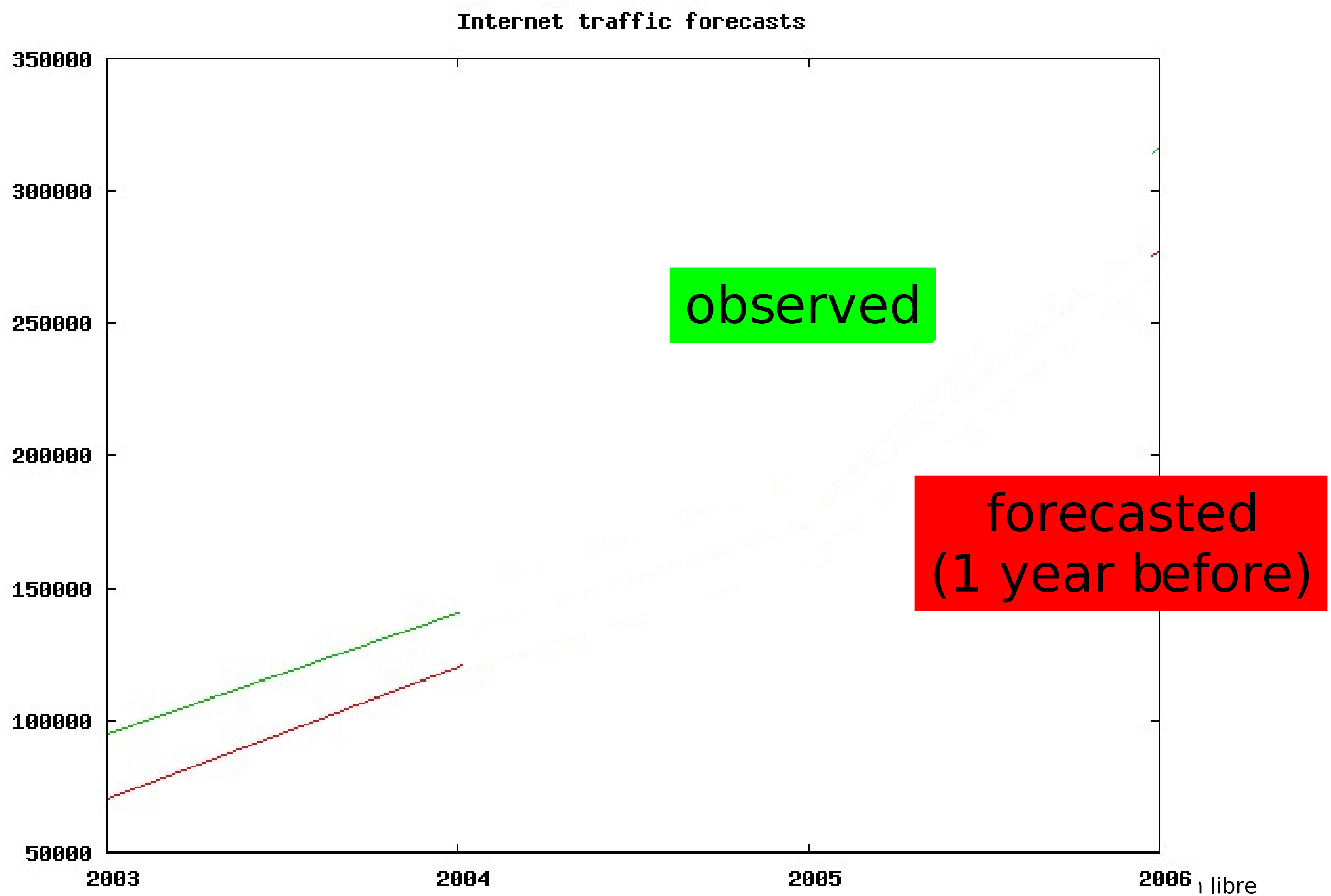
the hard work of forecasting...



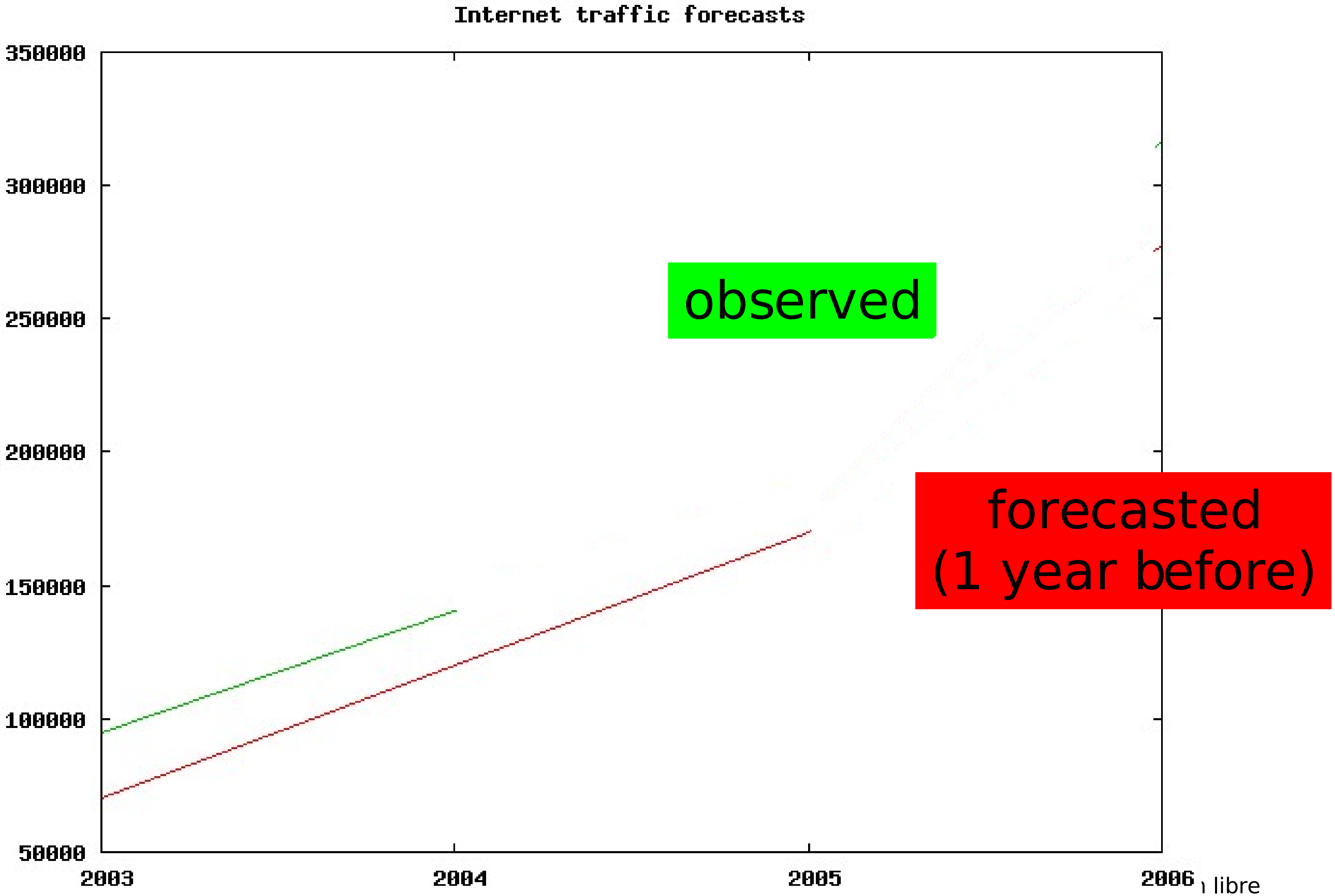
the hard work of forecasting...



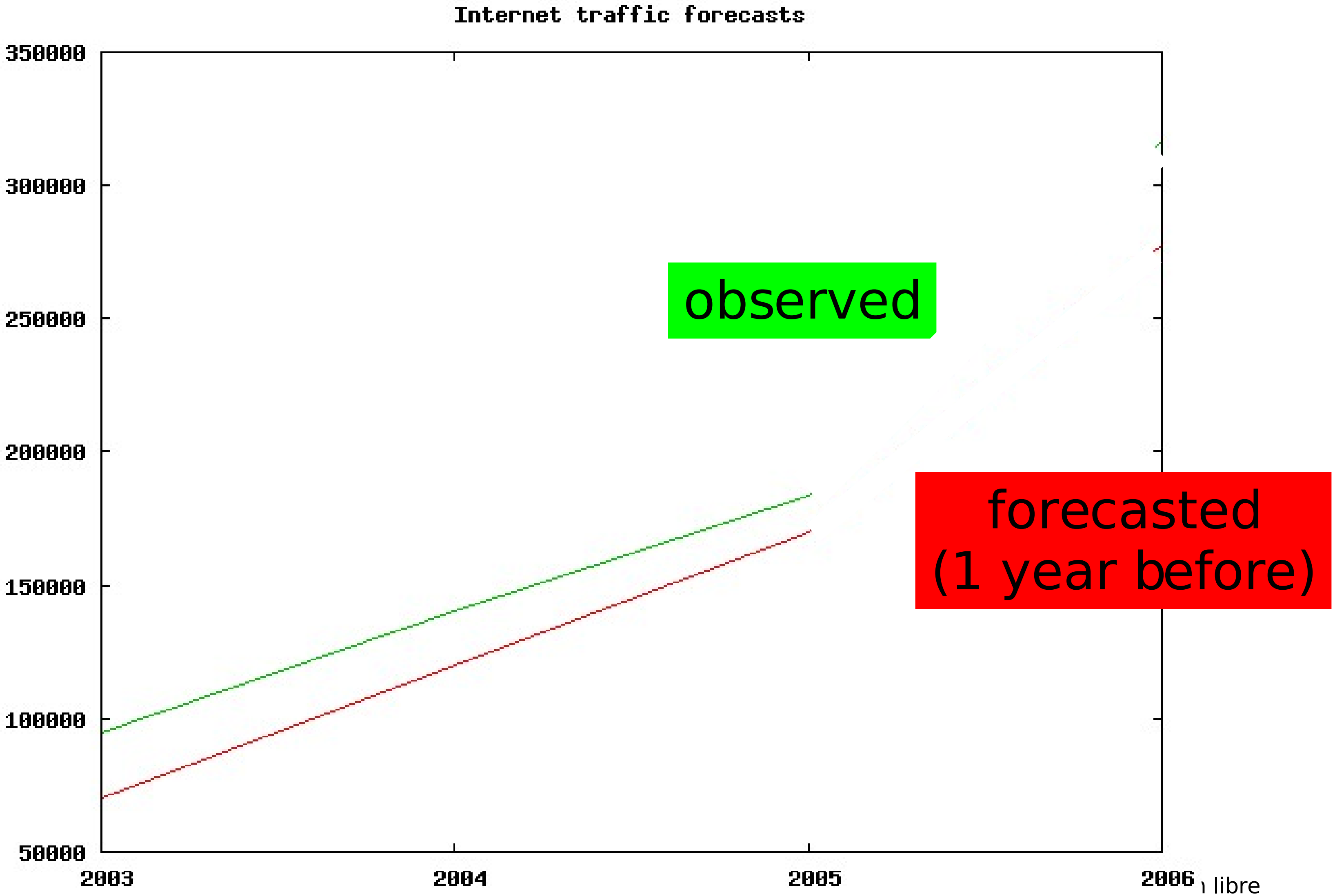
the hard work of forecasting...



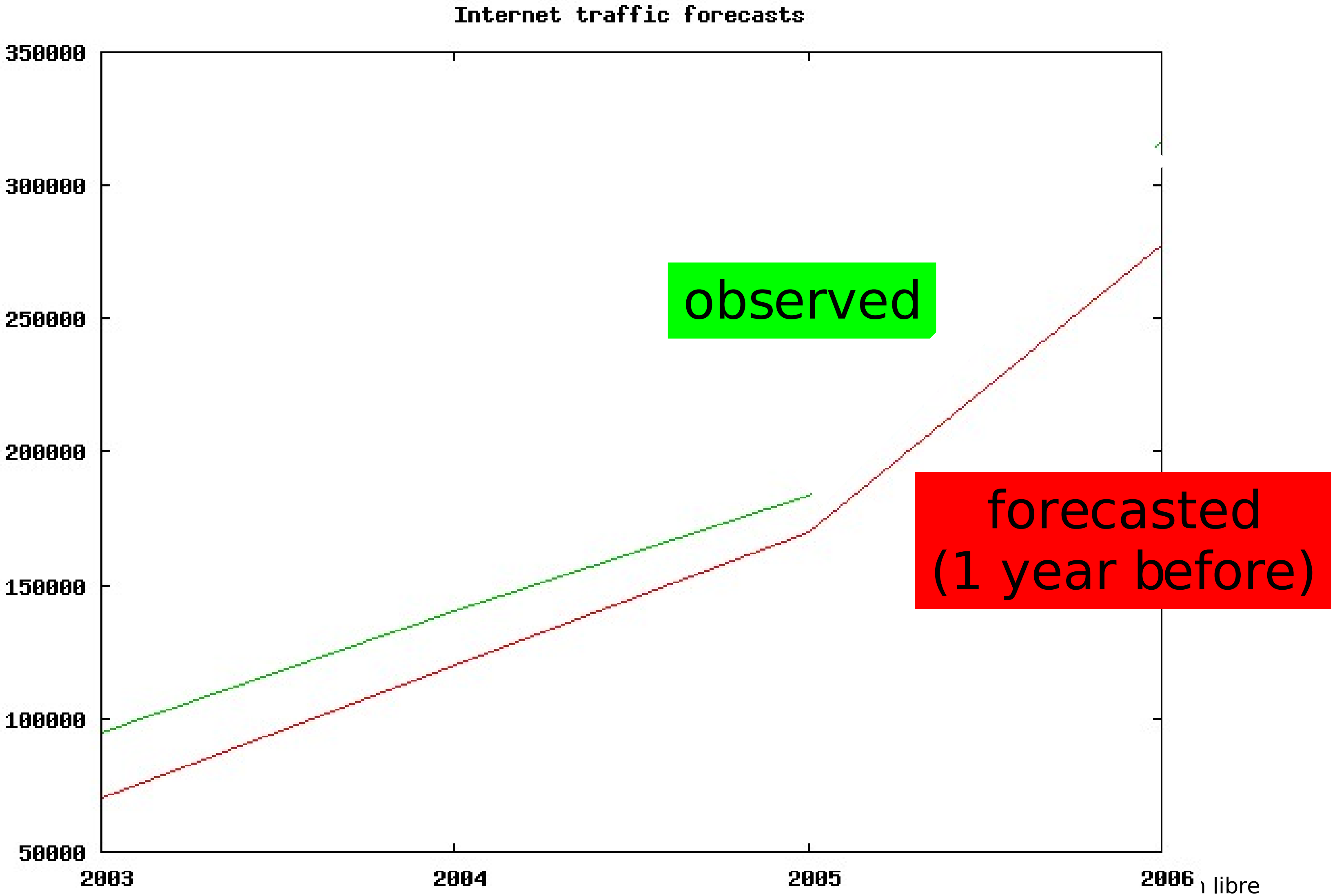
the hard work of forecasting...



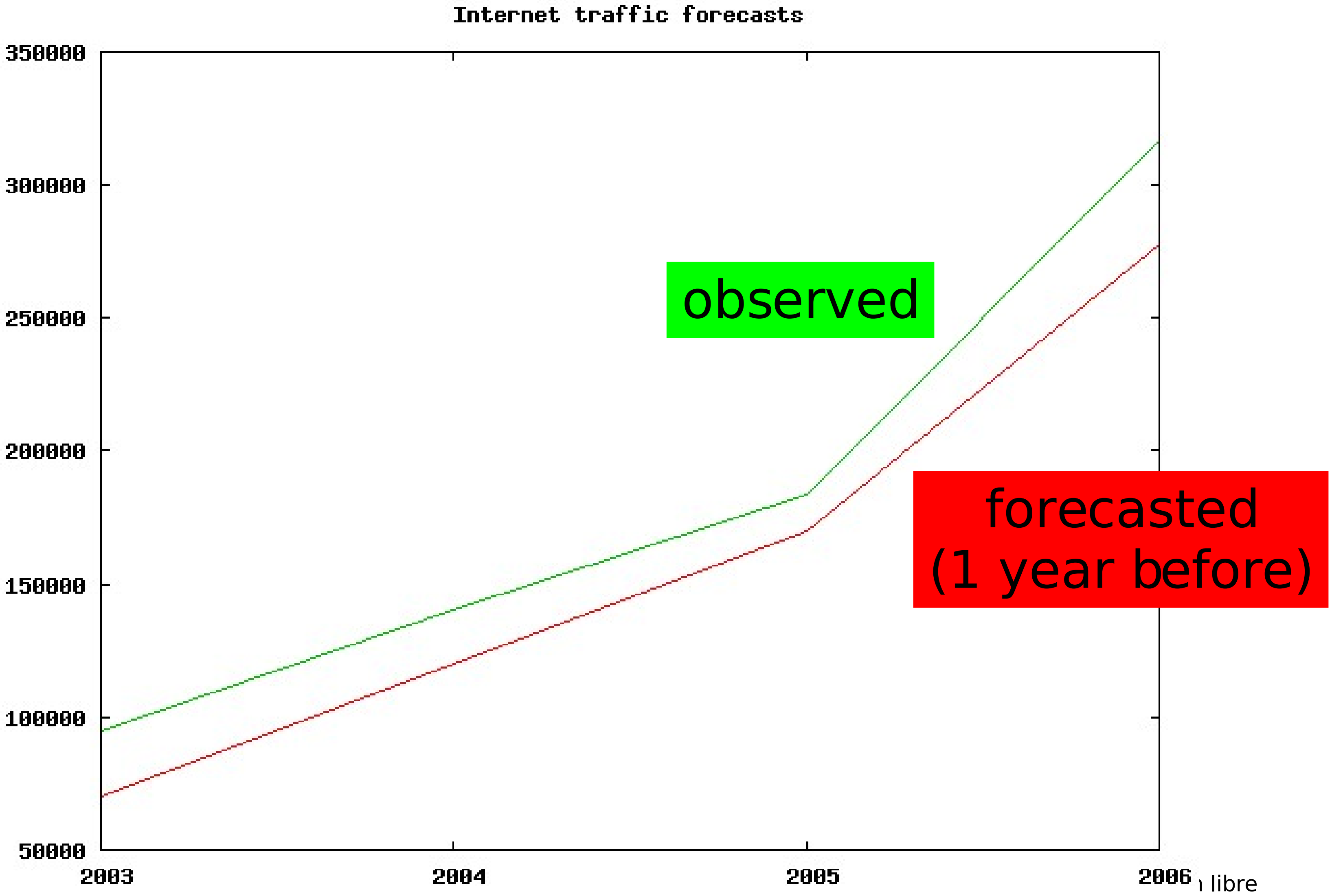
the hard work of forecasting...



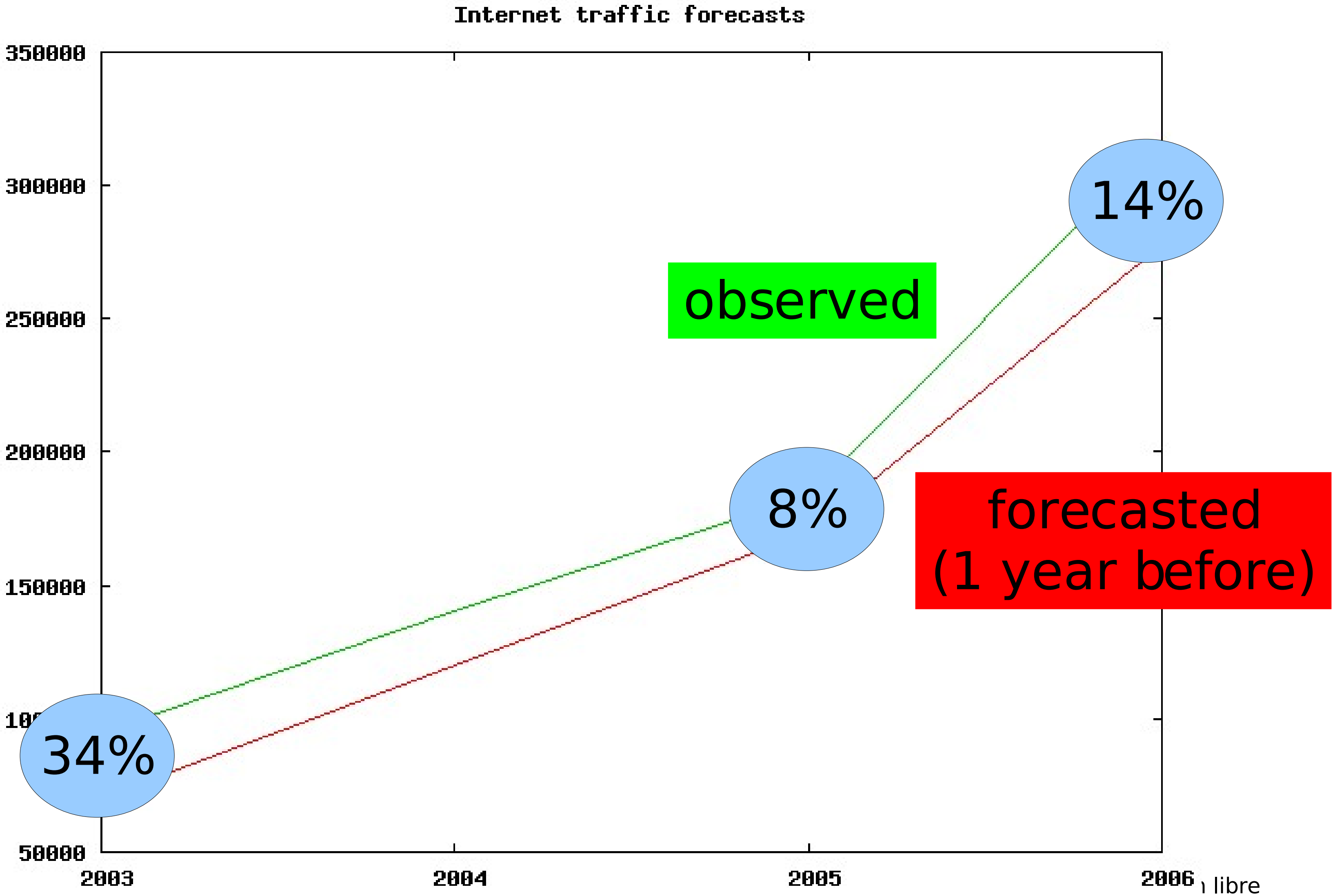
the hard work of forecasting...



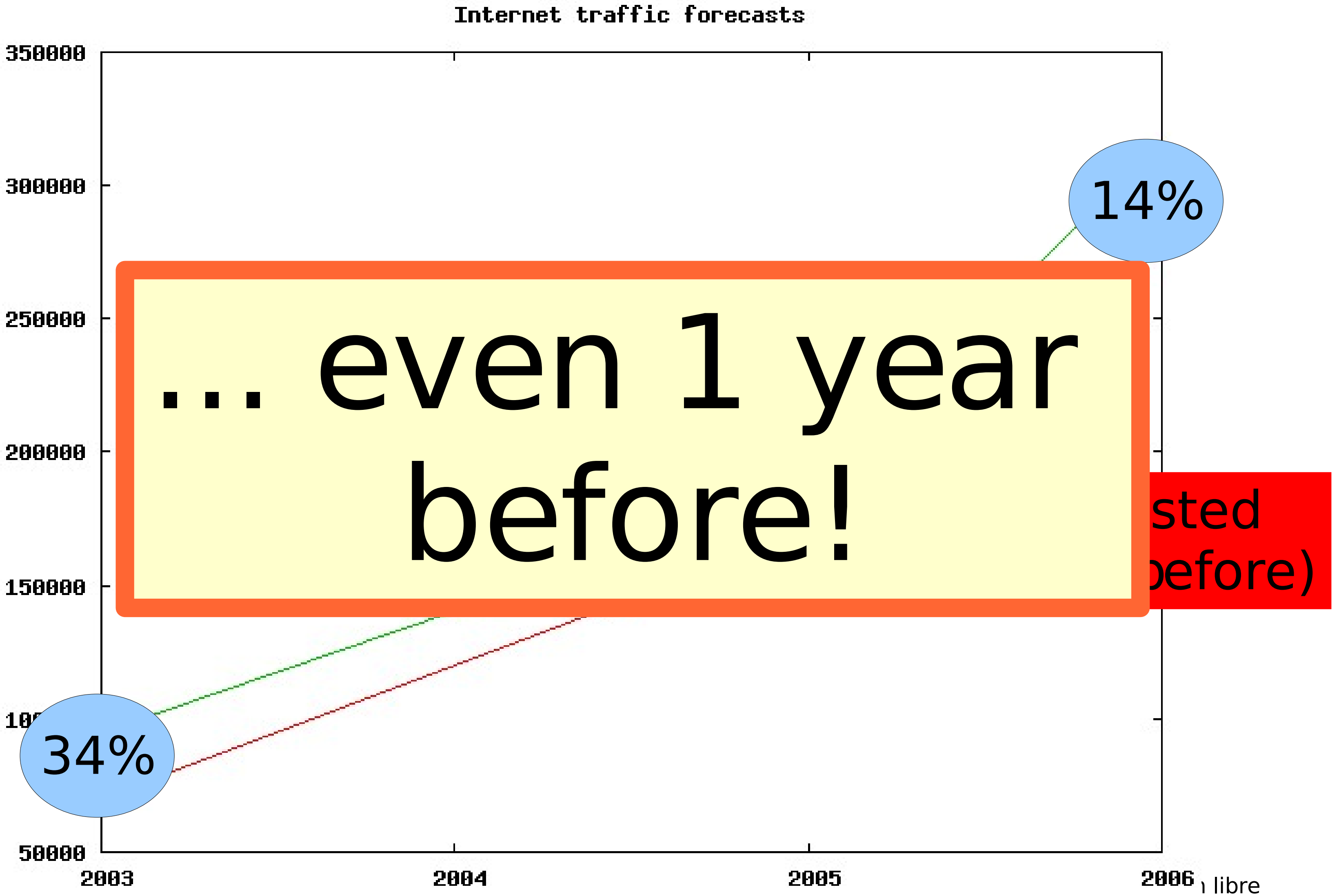
the hard work of forecasting...



the hard work of forecasting...



the hard work of forecasting...



new “hot topics” are highly impacted by uncertainty

- when introducing a new service, how to know the future number of subscribers?
  - no data history!

new “hot topics” are highly impacted by uncertainty

- when introducing a new service, how to know the future number of subscribers?
  - no data history!
- current hot topic: FTTH (Fiber To The Home)
  - what about future government and/or european regulation?
  - strong impact of competition on deployment
  - and of course, will there be a lot of subscribers?

new “hot topics” are highly impacted by uncertainty

- when introducing a new service, how to know the future number of subscribers?
  - no data history!
- current hot topic: FTTH (Fiber To The Home)
  - what about future government and/or european regulation?
  - strong impact of competition on deployment
  - and of course, will there be a lot of subscribers?
- however, we need to plan budgets and investments
  - more critically for a new service: we even need to decide to go or not!

how to deal with uncertain forecasts?

- in practice, most of the time, several scenarios are defined and successively evaluated

how to deal with uncertain forecasts?

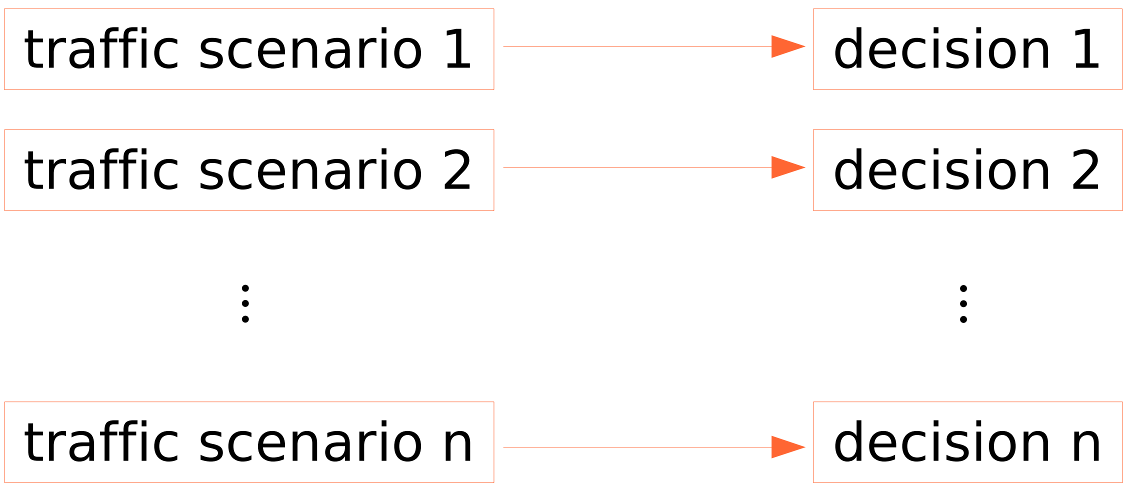
- in practice, most of the time, several scenarios are defined and successively evaluated

traffic scenario 1 → decision 1

traffic scenario 2 → decision 2

how to deal with uncertain forecasts?

- in practice, most of the time, several scenarios are defined and successively evaluated



how to deal with uncertain forecasts?

- in practice, most of the time, several scenarios are defined and successively evaluated

traffic scenario 1 → decision 1

traffic scenario 2 → decision 2

⋮ ⋮

traffic scenario n → decision n

- analysis and comparisons often very complex
- finally, how to choose one single decision?

the proposed approach

- basis: stochastic modeling of uncertain data
  - traffic, costs…
  - probability distribution

the proposed approach

- basis: stochastic modeling of uncertain data
  - traffic, costs…
  - probability distribution
- goal: find the best decision which will remain feasible for given targeted probability
  - e.g. find the lowest cost network architecture which will remain feasible with probability at least 0.95

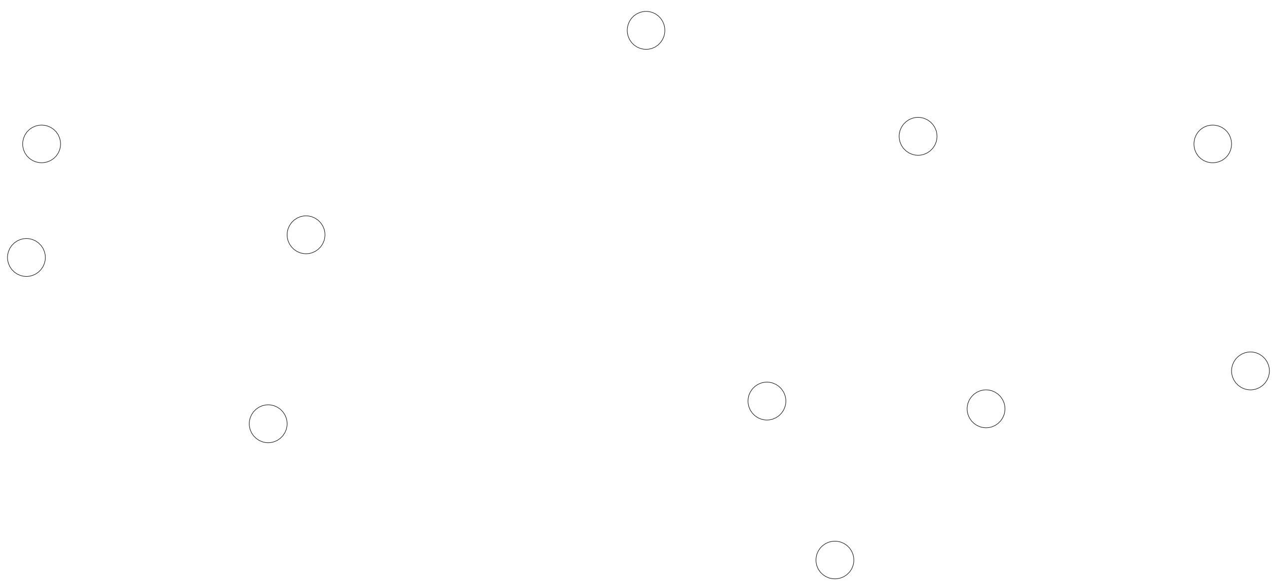
the proposed approach

- basis: stochastic modeling of uncertain data
  - traffic, costs...
  - probability distribution
- goal: find the best decision which will remain feasible for given targeted probability
  - e.g. find the lowest cost network architecture which will remain feasible with probability at least 0.95
- use of classical stochastic programming models
  - probabilistic constraints

outline

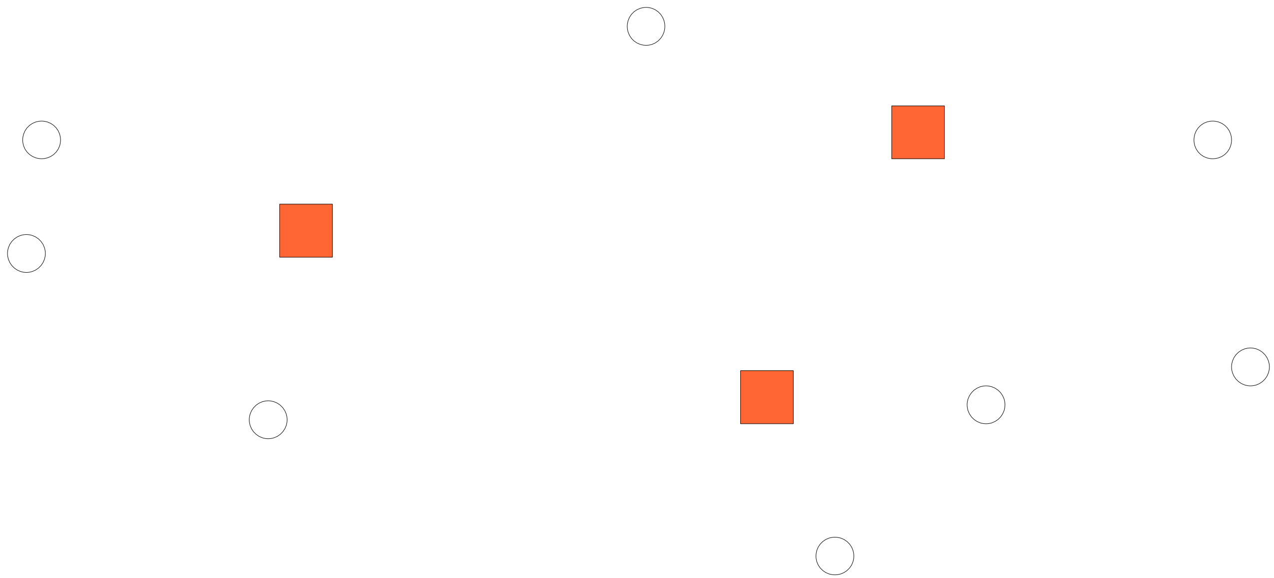
access network dimensioning

- basic problem: where to locate concentration equipments in a network?
  - applicable to almost all types of networks and services



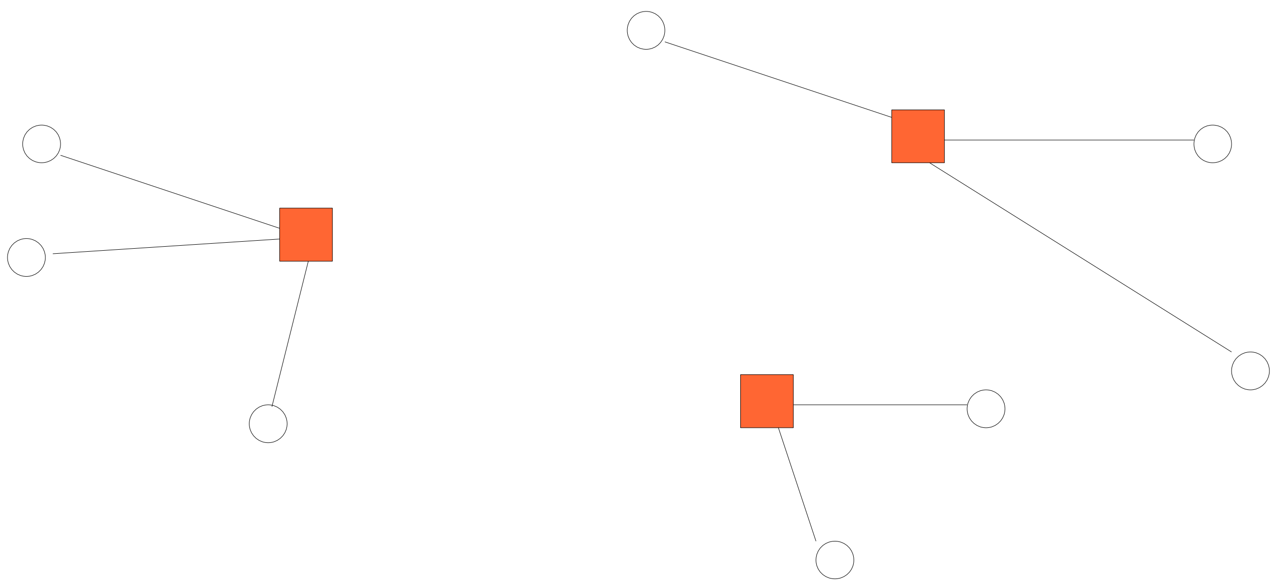
access network dimensioning

- basic problem: where to locate concentration equipments in a network?
  - applicable to almost all types of networks and services



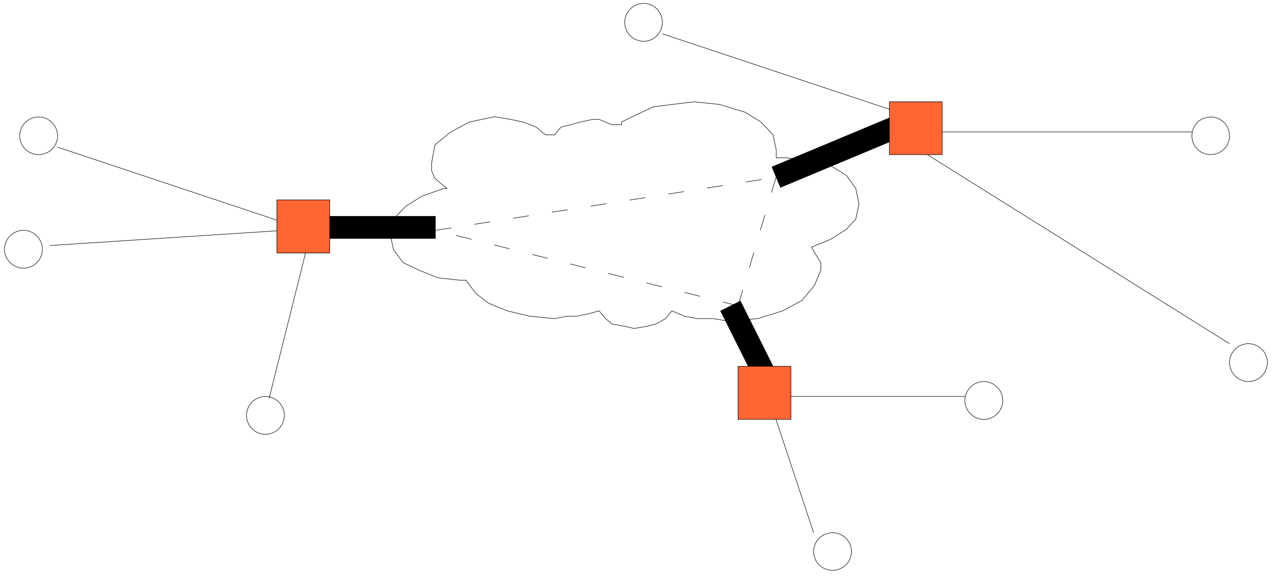
access network dimensioning

- basic problem: where to locate concentration equipments in a network?
  - applicable to almost all types of networks and services



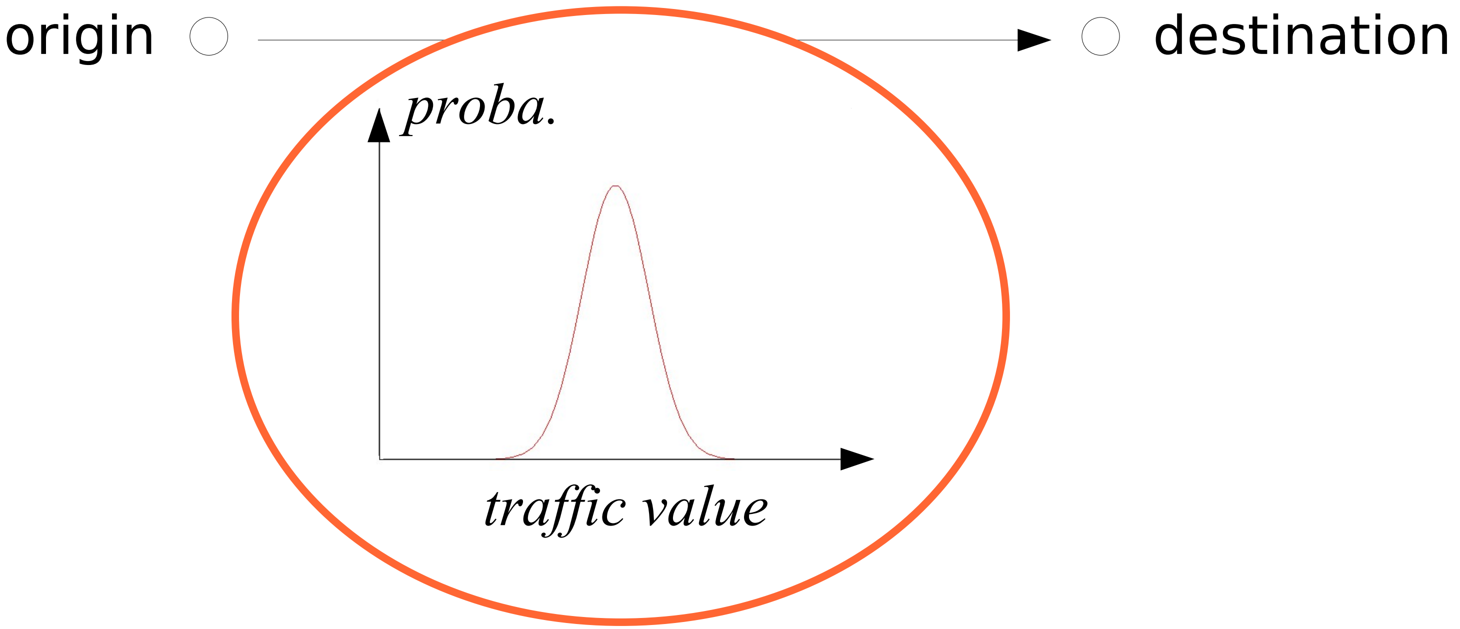
access network dimensioning

- basic problem: where to locate concentration equipments in a network?
  - applicable to almost all types of networks and services



stochastic modeling of traffic

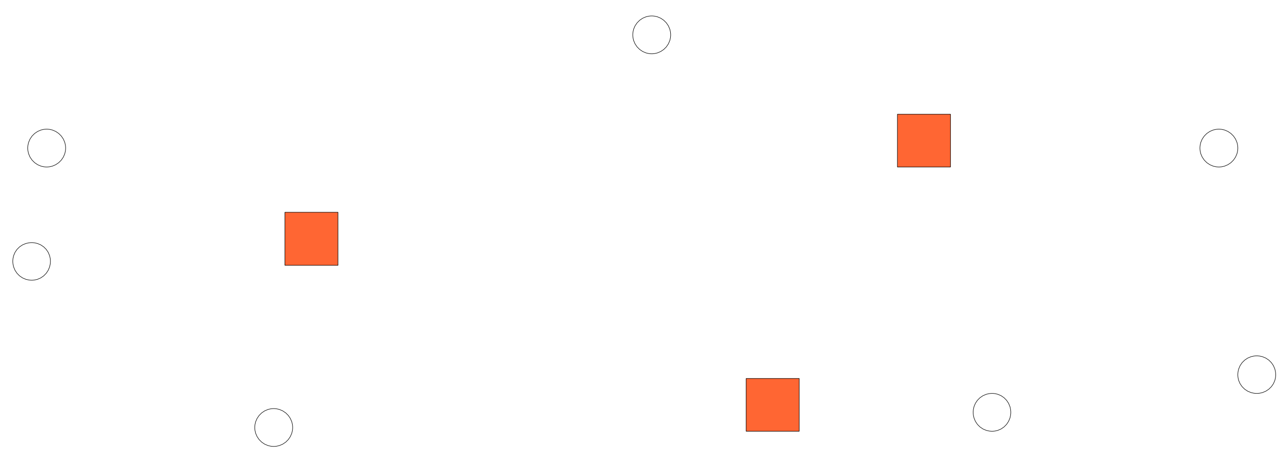
- uncertain traffic forecasts: gaussian model



- by default, traffic forecasts are supposed stochastically independent

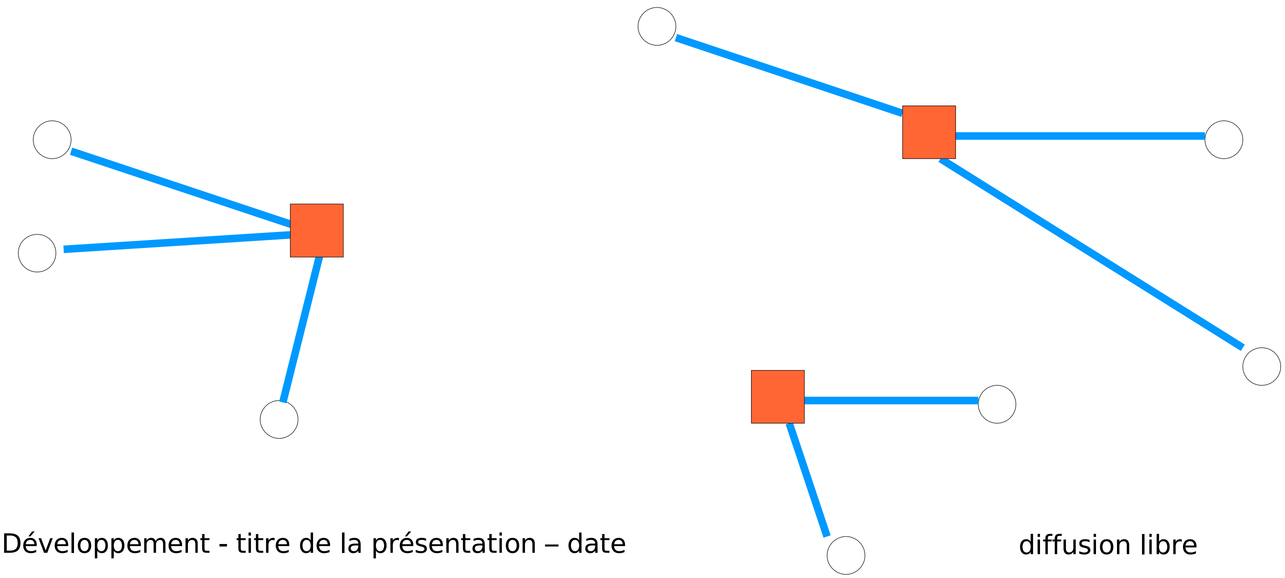
cost structure

- site equipments
  - with access and core cards



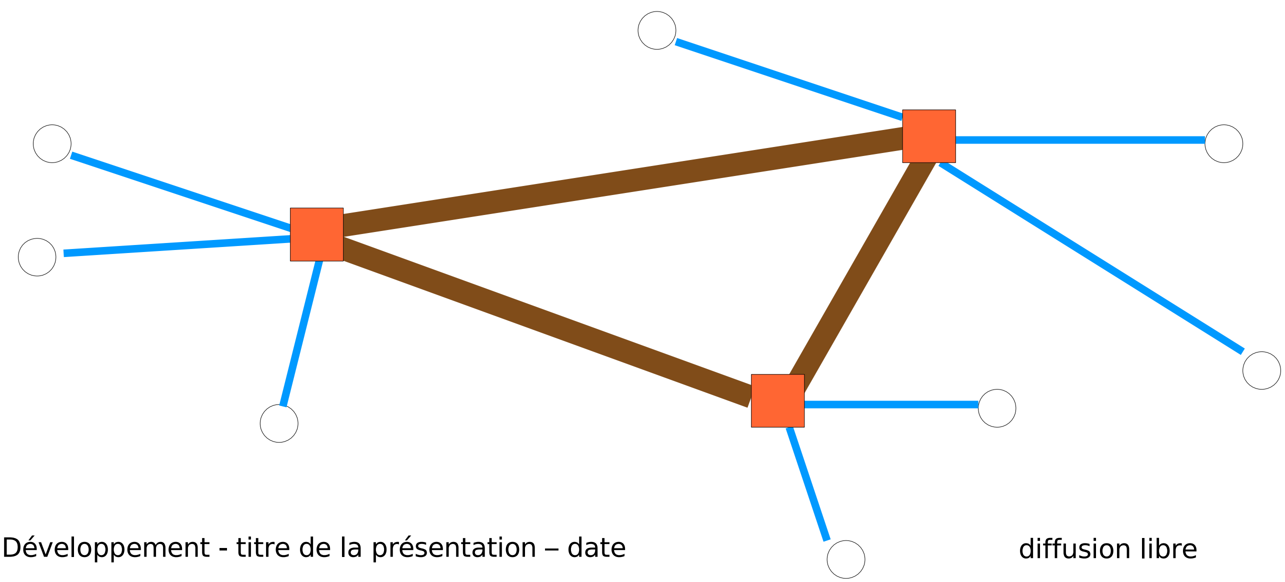
cost structure

- site equipments
  - with access and core cards
- access links
  - cost may depend on length, traffic, etc.



cost structure

- site equipments
  - with access and core cards
- access links
  - cost may depend on length, traffic, etc.
- core transport
  - idem



mathematical program

- “hub location” type model
- objective: total cost minimization

$$\sum_{(i,k)\in I^2} A_{ik} x_{ik} + \sum_{k\in I} \left(c_k^a y_k^a + c_k^b y_k^b \right) + \sum_{(k,l)\in I^2} B_{kl} z_{kl}$$

mathematical program

- "hub location" type model
- objective: total cost minimization

$$\sum_{(i,k)\in I^2} A_{ik} x_{ik} + \sum_{k\in I} \left(c_k^a y_k^a + c_k^b y_k^b \right) + \sum_{(k,l)\in I^2} B_{kl} z_{kl}$$

- not to go into details (cf paper), but dimensioning constraints look like:
  - for each concentrator site k:

$$P\left(K_b r_k \geqslant \sum_{i\in I} \left(\sum_{j\in I} t_{ij} \left[1 - x_{jk} \right] \right) . x_{ik} \right) \geqslant 1 - \varepsilon_b$$

mathematical program

- "hub location" type model
- objective: total cost minimization

$$\sum_{(i,k)\in I^2} A_{ik} x_{ik} + \sum_{k\in I} \left(c_k^a y_k^a + c_k^b y_k^b \right) + \sum_{(k,l)\in I^2} B_{kl} z_{kl}$$

- not to go into details (cf paper), but dimensioning constraints look like:
  - for each concentrator site k:

probability → $$P\left(K_b r_k \geqslant \sum_{i\in I} \left(\sum_{j\in I} t_{ij} [1 - x_{jk}] \right) . x_{ik} \right) \geqslant 1 - \varepsilon_b$$

mathematical program

- "hub location" type model
- objective: total cost minimization

$$\sum_{(i,k)\in I^2} A_{ik} x_{ik} + \sum_{k\in I} (c_k^a y_k^a + c_k^b y_k^b) + \sum_{(k,l)\in I^2} B_{kl} z_{kl}$$

- not to go into details (cf paper), but dimensioning constraints look like:
  - for each concentrator site k:

$$P\left(K_b r_k \geqslant \sum_{i\in I} \left(\sum_{j\in I} t_{ij} [1 - x_{jk}]\right) . x_{ik}\right) \geqslant 1 - \varepsilon_b$$

probability → P

installed capa. → $K_b r_k$

mathematical program

- “hub location” type model
- objective: total cost minimization

$$\sum_{(i,k)\in I^2} A_{ik}\, x_{ik} + \sum_{k\in I} \left(c_k^a\, y_k^a + c_k^b\, y_k^b \right) + \sum_{(k,l)\in I^2} B_{kl}\, z_{kl}$$

- not to go into details (cf paper), but dimensioning constraints look like:
  - for each concentrator site k:

$$P\left(K_b\, r_k \geqslant \sum_{i\in I} \left(\sum_{j\in I} t_{ij} \left[1 - x_{jk} \right] \right) . x_{ik} \right) \geqslant 1 - \varepsilon_b$$

probability

installed capa.

stochastic traffic

mathematical program

- “hub location” type model

- objective: total cost minimization

$$\sum_{(i,k)\in I^2} A_{ik}\, x_{ik} + \sum_{k\in I} \left(c_k^a\, y_k^a + c_k^b\, y_k^b\right) + \sum_{(k,l)\in I^2} B_{kl}\, z_{kl}$$

- not to go into details (cf paper), but dimensioning constraints look like:
  - for each concentrator site k:

$$P\left(K_b\, r_k \geqslant \sum_{i\in I}\left(\sum_{j\in I} t_{ij}\left[1-x_{jk}\right]\right).\, x_{ik}\right) \geqslant 1-\varepsilon_b$$

risk management

probability

installed capa.

stochastic traffic

outline

solution algorithm

- the problem is far too complex to be solved optimally, given the state of the art in mathematical programming
- heuristic approach: simulated annealing
- note: gaussian assumptions make analytical calculations of costs possible

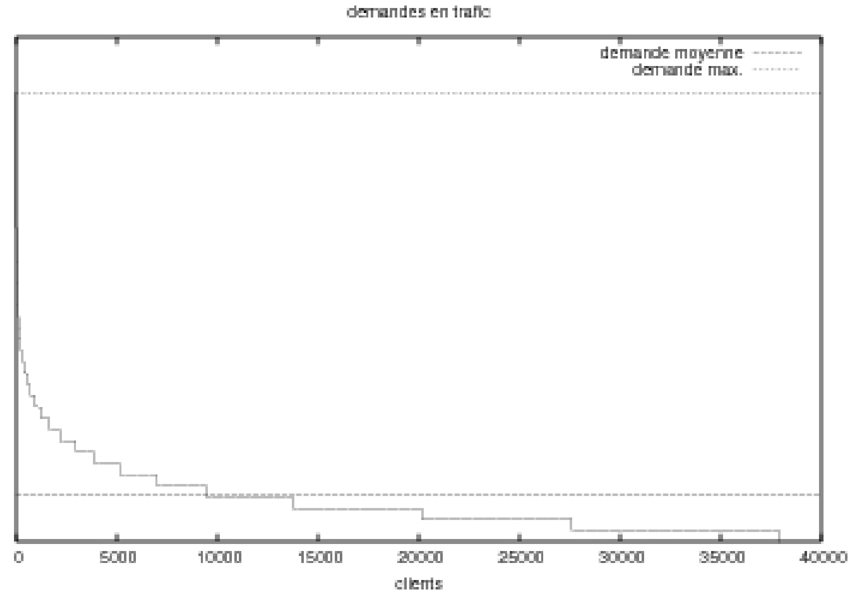
description of data (1/2)

- instance size (from a real-life case)
  nb of client sites = 276
  nb of possible concentrator sites = 85
  nb of possible access links = 42556

- equipments for concentrator sites
  access cards: 8 slots with capa. K_a
  backbone cards: 2 slots with capa. $K_b = 4.K_a$
  backbone card cost = 0.6 * access card cost

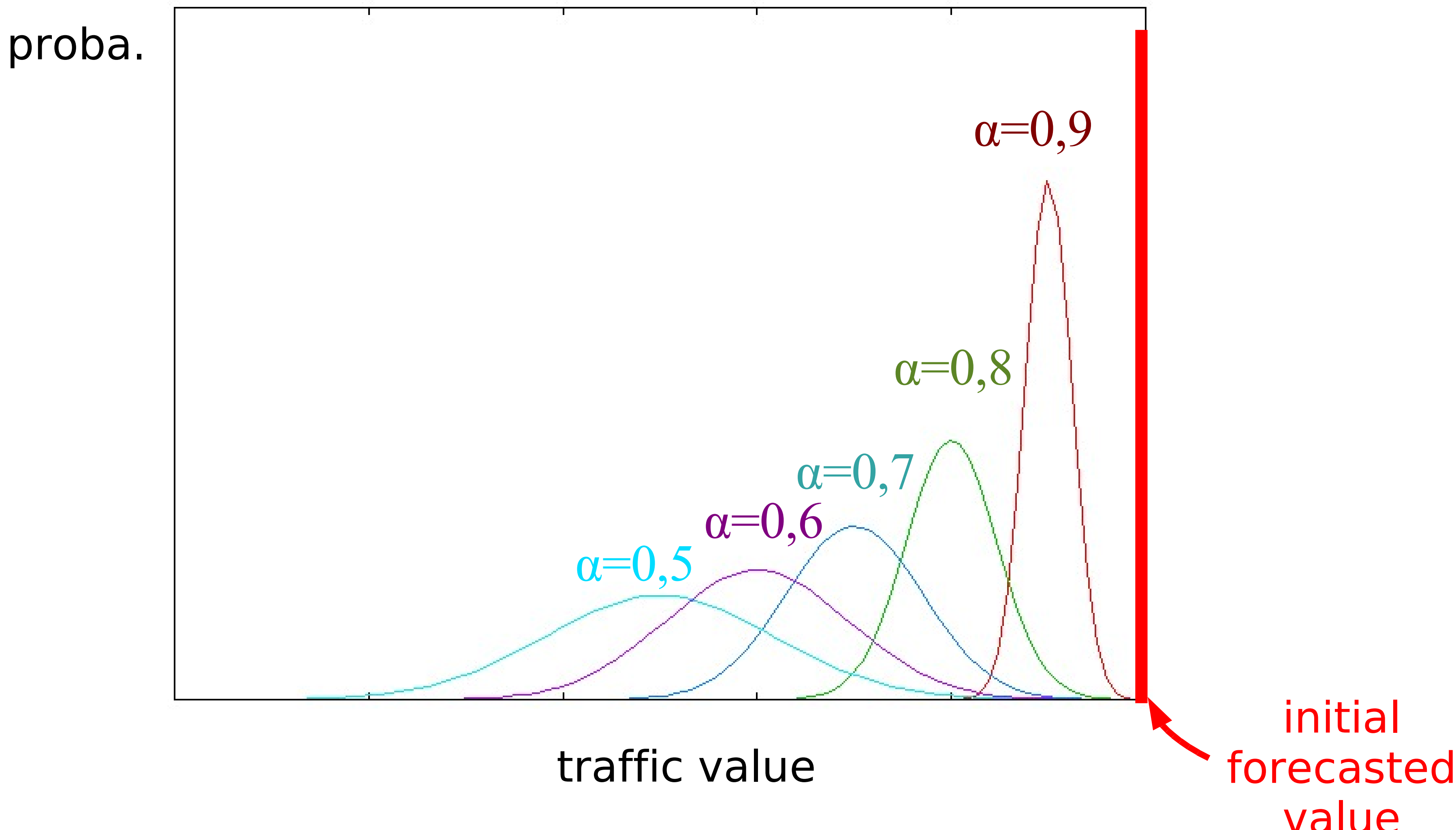
traffic data

- initial traffic forecasts:

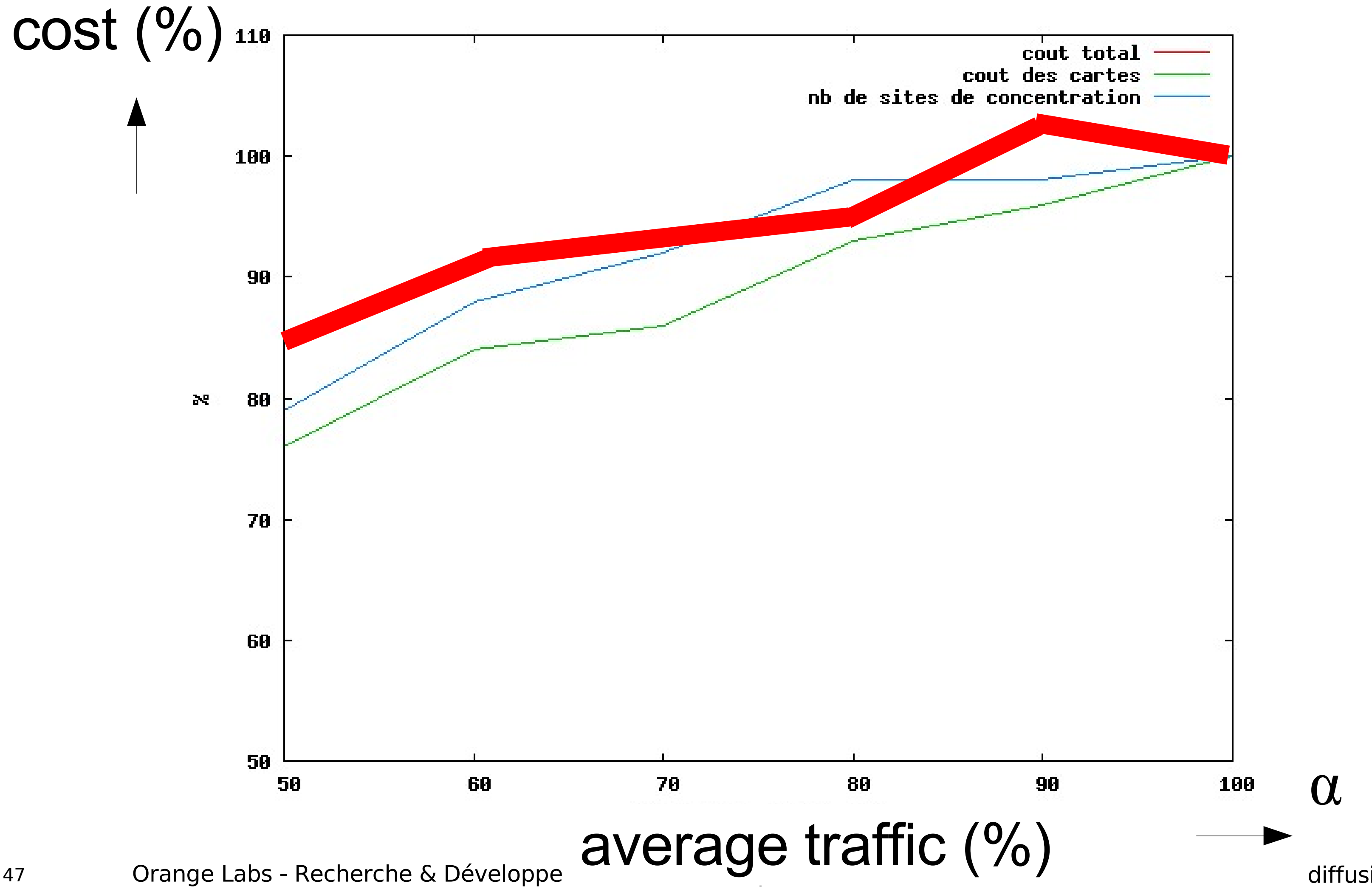


- assumption: these scalar data are over-evaluated (optimistic)
  - this is often the case when introducing a new service

going to stochastic traffic data



best architecture cost with proba. 0.9



analysis

- gain of 15% on the total cost when the average (stochastic) traffic is 50% of the forecasted value
  - recall that we ensure that 90% of the traffic scenarios will be accommodated by the computed architecture
- computation time: about 30 minutes

conclusion

- stochastic models given for dimensioning an access network
  - probabilistic constraints
- definition of a heuristic solution algorithm

conclusion

- stochastic models given for dimensioning an access network
  - probabilistic constraints
- definition of a heuristic solution algorithm
- the computed solution accommodates traffic scenarios with probability at least 0.9
  - only adjustment variable: the average traffic value

conclusion

- stochastic models given for dimensioning an access network
  - probabilistic constraints
- definition of a heuristic solution algorithm
- the computed solution accommodates traffic scenarios with probability at least 0.9
  - only adjustment variable: the average traffic value
- methodology to compute the best architecture:
  - for an expected scenario (average)
  - with possible traffic variations and probabilistic guarantees

thank you