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Mobile Broadband. **Everywhere.**

Using NTP for network synchronisation of 3G femtocells

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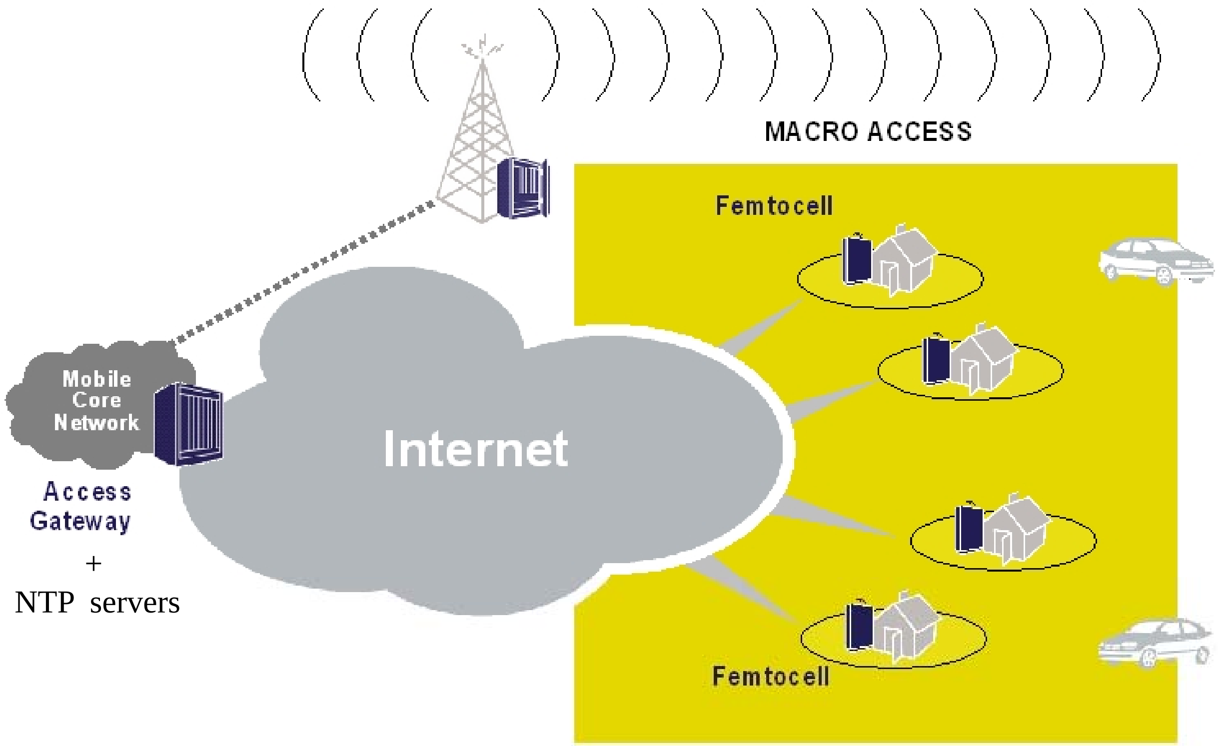
Munich, October 2008

Content

- Synchronisation requirements for 3G femtocells
- Methods available for meeting frequency error requirements of 3G femtocells
- NTP: network load and effects of packet jitter
- Measurements, model and simulation of packet network delays
- Conclusions

The 3G femtocell

- In this presentation, the *3G femtocell* (or Home NodeB) is intended as a *consumer device* aimed to provide *UMTS-WCDMA* services in residential areas
- The *3G femtocell* connects to the service provider’s network via residential broadband (such as DSL or cable) at the customer premises



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Enter The Femtocell

Issue	Femtocell Impact
Coverage	Subscriber self-selects antenna location where usage occurs for excellent in-home coverage
Data Performance	Spectrum shared among 1-4 users for highest possible data rates
CAPEX	Small consumer electronics device
OPEX	Backhaul via existing wired broadband infrastructure; no incremental power, property leases.

"Enter the femtocell: a little box with a whole lot of promise."

Fox News, November 2007

3G femtocell challenges

- The femtocell extends the functionality of a typical base station to allow a simpler, self contained deployment

- "*Femtocells are initially expected to cost in the low hundreds of dollars. ... Over time, the price of femtocells is expected to decline as volumes increase*" (from Airvana's Web site)

- The technical challenges associated with a mass market femtocell solution are significant. From a consumer point of view:
  - the solution must be as painless to install and use as an existing cordless telephone or wireless router
  - consumers will expect to have the system up and running in a matter of minutes.

Frequency accuracy requirements for the 3G femtocell

- 3GPP requirements for WCDMA Base Stations RF characteristics are specified in 3GPP TS25.104
- The frequency error requirements for the Home BS have been recently relaxed from 100ppb to 250ppb (release 8 of the specifications)
- From TS25.104: "*The modulated carrier frequency of the BS shall be accurate to within the accuracy range [...] over a period of one timeslot*"
- In UMTS-WCDMA no time synchronisation between cells is required

Choice of oscillators for the 3G femtocell

- Stress compensated oscillators (e.g. OCXO):
  - High costs (also due to heat dissipation requirements)
  - Due to long term ageing (min 5years) and mechanical shock effects, these may still require frequency discipline

- Digitally temperature compensated 'A-T' cut crystals (TCXOs):
  - Price more appropriate for consumer device
  - A number of vendors have products with the required specifications
  - Ageing (few days) requires external frequency discipline mechanism
  - Reduced useful temperature range

Frequency discipline technologies applicable to the 3G femtocell

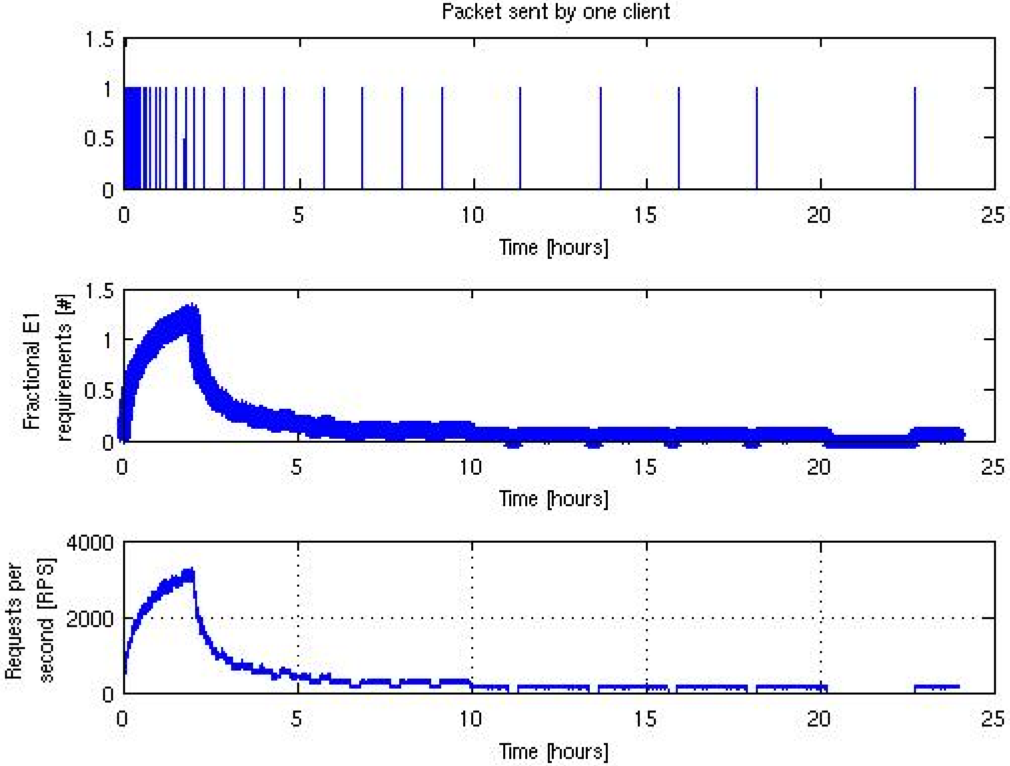
- In order to maximise the number of femtocells being able to discipline frequency, a number of synchronisation technology can be employed.
  - Over The Air (OTA) synchronisation:
    - GPS
    - Cellular macro networks
      - WCDMA
      - Other RAT's (e.g. GSM)
  - Packet network synchronisation
    - NTP or IEEE1588/PTP

Use of NTP for disciplining frequency

- NTP is one of the technologies which can be used to provide frequency discipline
  - Advantages:
    - » Low cost (clients and NTP Servers)
    - » Low network load
    - » No extra network elements required (e.g. edge clocks)
    - » Designed to work on “consumer network” quality
  - Disadvantages:
    - » Affected by packet network jitter
    - » Slow initial convergence
      - » Can be improved by employing other frequency discipline mechanisms at start up
    - » No possible to correct for temperature effects
      - » Use of high quality temperature compensated 'A-T' crystals

Network requirements for NTP

- Simulation of network load at the MNO
  - 1,000,000 clients are randomly started within 2hours (e.g. after city blackout or a national network outage)
  - The clients poll 4 NTP servers
  - Polling period 2^14s (+/-6ppb precision).
  - The analysis only include UDP-IP packets (including NTP headers),
  - No queuing is employed at the NTP server, as it would increase jitter



  - The aggregated network load for 1milion HNB, requires ~1.3xE1 connections
  - Current NTP servers are able to server up to 20,000 Request-per-second

  - Note that, the analysis only takes into consideration the packet arrival at the server, no assumptions are made on the quality of synchronisation of the clients.

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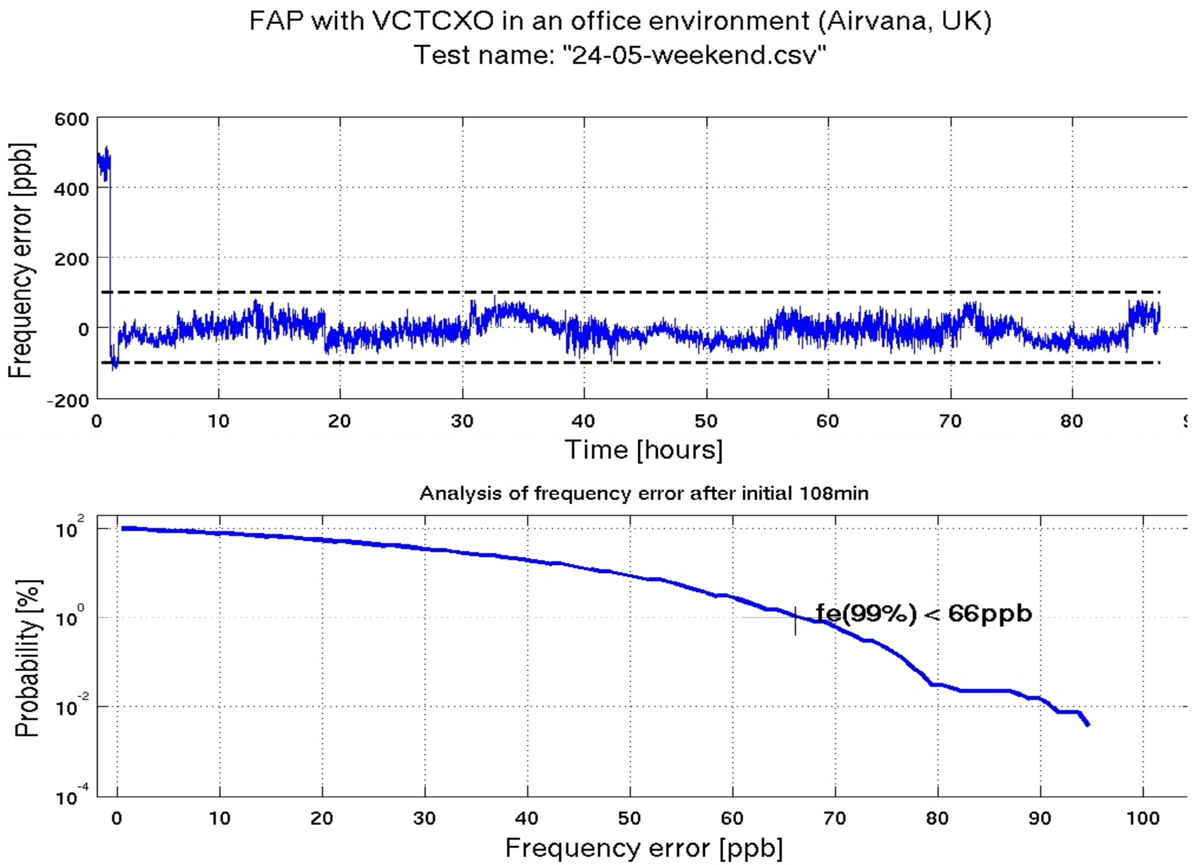
Example of frequency discipline with (F)NTP*

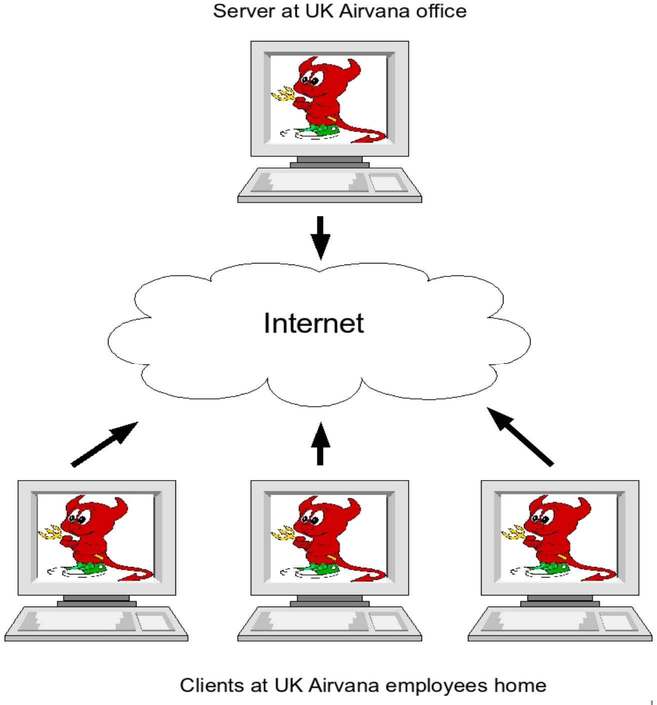
- Large initial error of 500ppb is assumed.
- Simple synthetic exponential network jitter
- Initial correction overshoot error is due the non linearity of the calibration which is accentuate by the large initial error. Over The Air synchronisation would mitigate these effects.
- Effect of temperature variation are not corrected by NTP



* Frequency NTP is Airvana proprietary optimisation on NTP

Effects of packet networks on frequency discipline

- Jitter in packet networks is the major factor in obtaining good frequency stability when using NTP.



- A number of real packet networks, which include consumer grade ADSL and digital CATV, were measured employing a stream of RTP packets in both direction from a client and a server. The data is used to quantify jitter in real consumer networks

- Performance of NTP is tested using a statistical model of jitter, the model can be used to measure limiting value of jitter for NTP to correctly discipline the oscillator

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Measurements of jitter

- Here, “packet delay” is used to describe the inter-arrival time between packets (not the average delay or latency). This value only describes the instantaneous effects due to congestion.

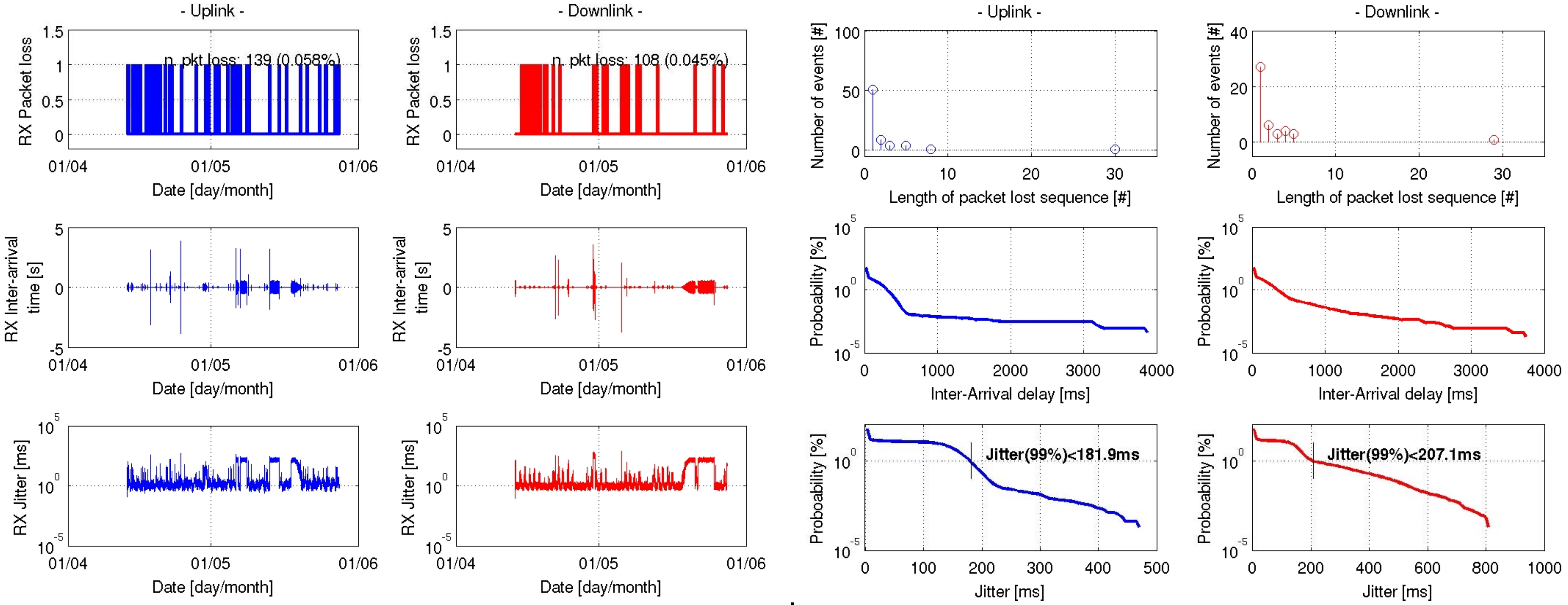
- The term “jitter” describes the statistical variance of packet arrival. It is calculated as the biased running average of the packet inter-arrival delay described above. It is measured from a stream of RTP packets as defined in [RFC3550]. The formula for calculating jitter (*J(i)*) at time *i* is:

$$J(i) = J(i-1) + \frac{\left| D(i-1,i) - J(i-1) \right|}{16}$$

- where, *J(i-1)* is the jitter for the previous sample and *D(i-1,i)* is the inter-arrival time between the two packets.

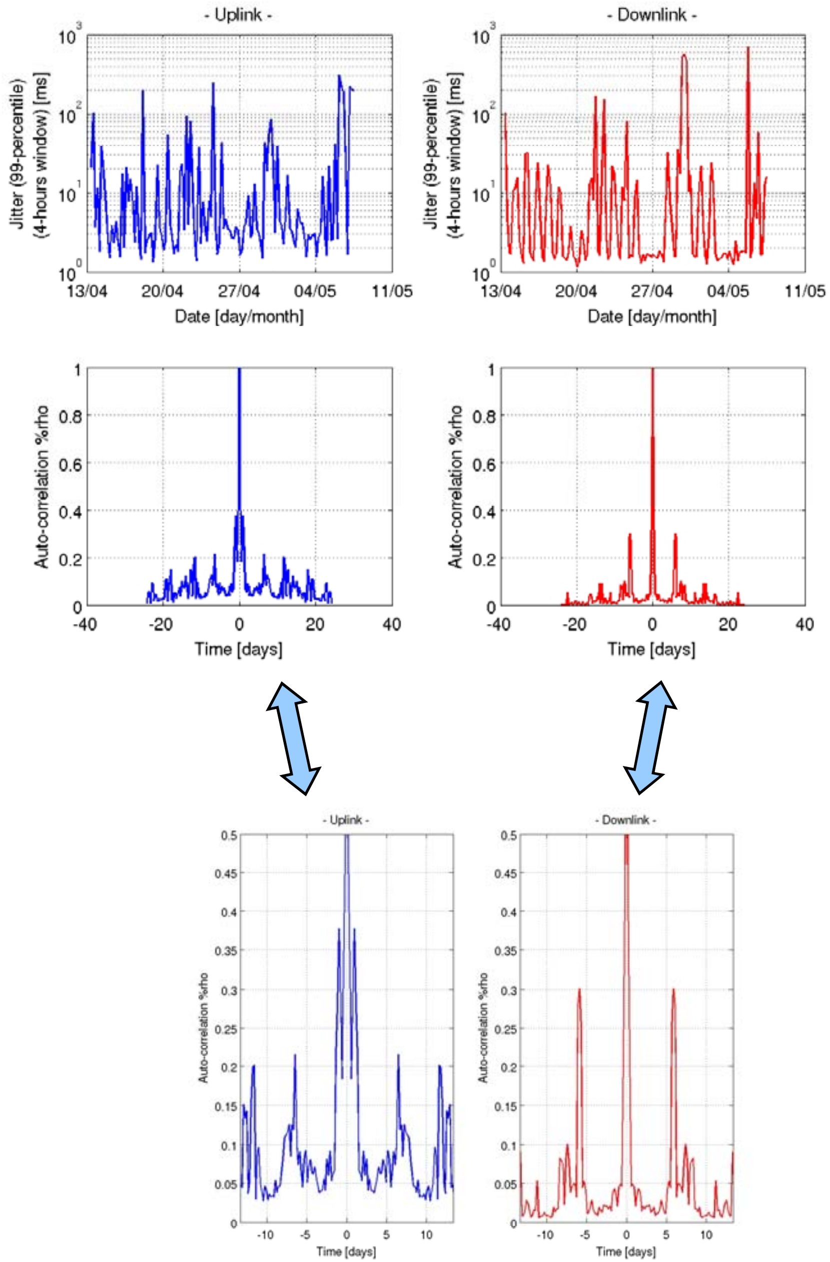
Packet delay and jitter measured on an ADSL line

- Server is on a “business quality” ADSL connection
- Clients is on consumer ADSL connections
- Standard home routers/modems at customer site
- UDP (RTP-like) packets are sent every 16s



Analysis of jitter

- Details analysis of packet jitter shows its variability
- Peaks of the autocorrelation of measured jitter, implies period of time where congestion is most likely to affect frequency discipline
- Uplink and downlink shows different jitter profiles
- No possible to identify a “simple” model



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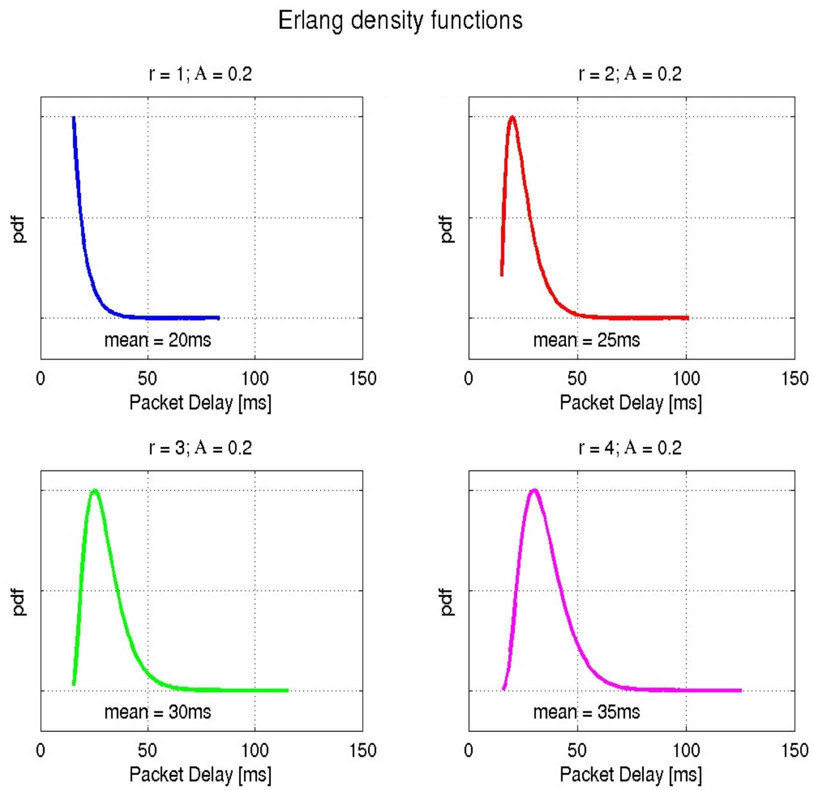
Jitter model for testing NTP

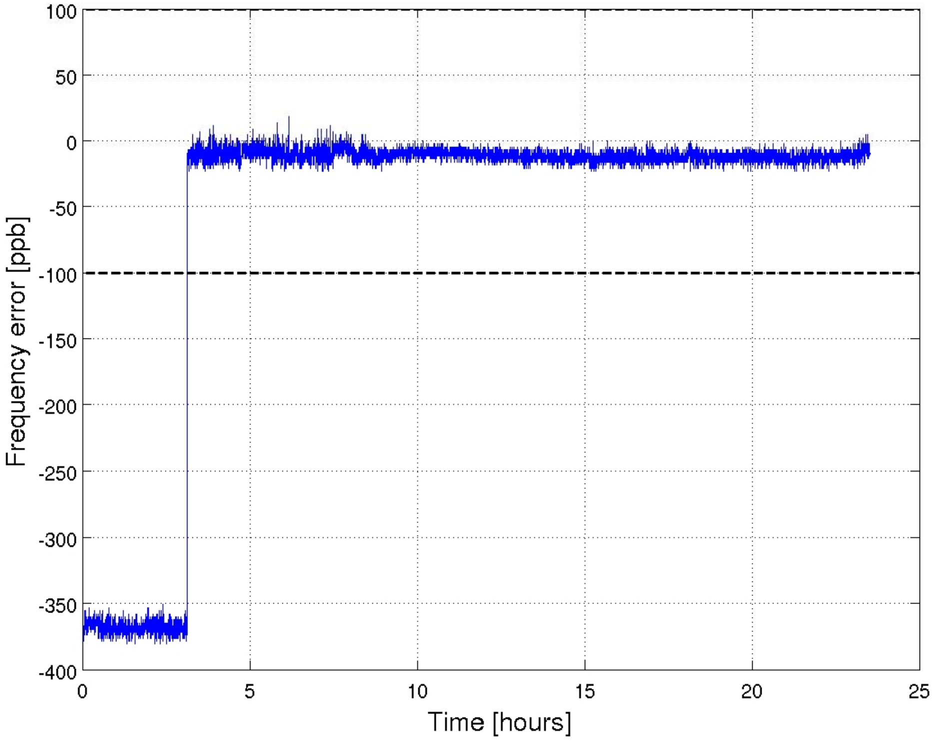
- The model assumes that network delay is made of two components:
  - a fixed delay
  - a random component with an Erlang distribution which varies during the day

- The delay of each packet is the sum of the delay of each queue encountered in the path. Further assuming that each queue delays the packets with an exponential distribution, it leads to the Erlang distribution.



Test results of (F)NTP on a network with synthetic packet jitter

- Test with an OCXO (no temperature effects)
- Network jitter simulates daily variations, parameters value are to be provided from measurements
- 360ppb initial error, converged within 3.5hours
- NTP is able to maintain good frequency stability



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Reducing convergence time and limiting effects of network jitter

- Use of OTA synchronisation previous of starting NTP
- Periodically run OTA synchronisation to improve frequency stability
- Use OTA synchronisation during high packet jitter periods
- Estimates of frequency stability can be used for limiting effect of high packet jitter periods
- Monitoring of environmental temperature, may be used to mitigate frequency errors outside the correction range of TCXOs

Conclusions

- The 3G femtocell market is expected to be very large
- The 3G femtocell requires high quality TCXOs... at a cost compatible with a mass market device
- Several technology needs to be used on the 3G femtocell for frequency discipline
- Accurate frequency discipline is achievable with NTP
- Alternative technologies must be used for discipline the clock when NTP fails
- Algorithms for faster convergence are required

Thank you.

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