Wireless Sensor Network Synchronisation- D-FTSP

Jonathan Shannon , Hugh Melvin
Antonio Ruzzelli*

Discipline of Information Technology, National University of Ireland, Galway
*UCD School of Computer Science & Informatics

Funded by IRCSET - www.ircset.ie

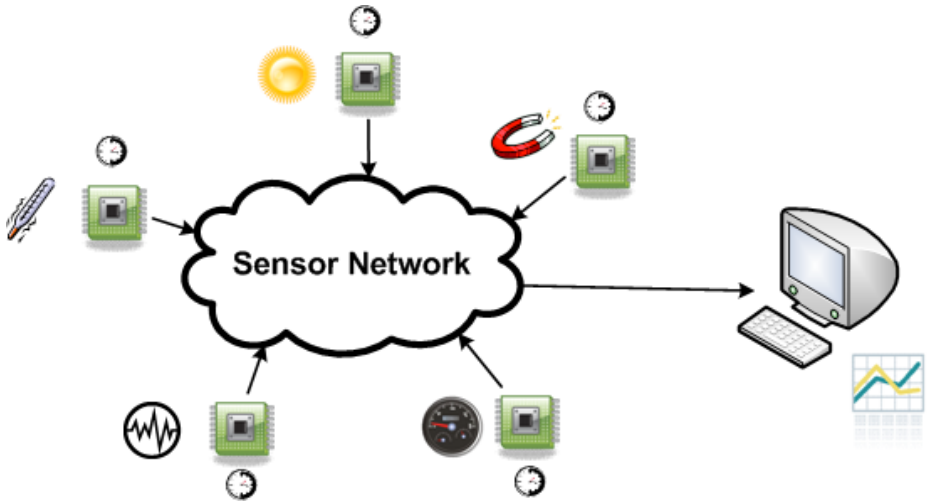
Performance Engineering Laboratory
pel.it.nuigalway.ie

Outline

- Wireless Sensor Networks (WSNs)
- Wireless Sensor Network Applications
- WSN Synchronisation
  - FTSP
  - D-FTSP
- Experiments
- Results

Wireless Sensor Networks (WSN)

- Miniature computing devices
- Sample Platform
  - 8 MHz
  - 10kB RAM
  - 802.15.4 Transceiver
- Limited battery power
- Sense and collect physical data



[1]

WSN: Market ForecastsOSNA

OSNA research

Market	Market Size in USD (Irl/EU/North America/USA/ Global)	Driver
Patient Monitoring	EU: 105.7 Mio (2010), 176.9 Mio (2015)	Health care modernisation
	USA: 339.3 Mio (2010), 1500 Mio (2015)	
Industrial Application (including DC)	EU: 13.2 Mio (2010), 30.7 Mio (2014)	Improved competitiveness
In-Building (Building Automation)	EU: 38.7 Mio (2010), 83.8 Mio (2014)	Energy costs
	NAm: 741.3 Mio (2010), 1521.2 Mio (2016)	
	Glb: See	
Smart grid	Irl: 4 Mio (2010), 7 Mio (2014)	Government directives
	EU: 40.8 Mio (2010), 70.7 Mio (2014)	
	USA: 395.2 Mio (2009), 2743.6 Mio (2014)	
Environmental Monitoring	Glb: 40 Mio (2009), 79 Mio (2014)	Environmental awareness

WSN

- IEEE 802.15.4
  - Underlying Physical/Data Link Layer for WSN
- Zigbee
  - Implements higher layers on top of 802.15.4
- 6LoWPAN
  - Alternative to Zigbee
  - IPv6 (or v4) on top of 802.15.4
- + others

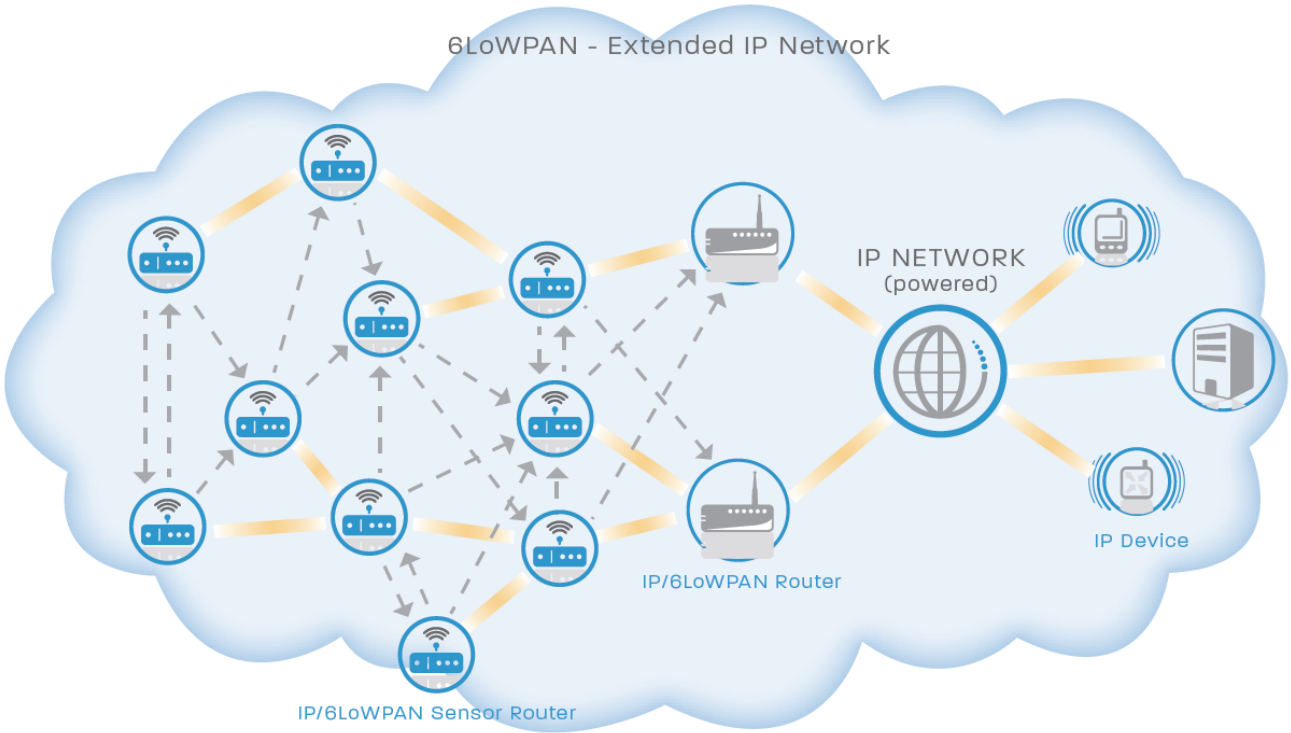
OSI Model
Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

WSN: Related concepts

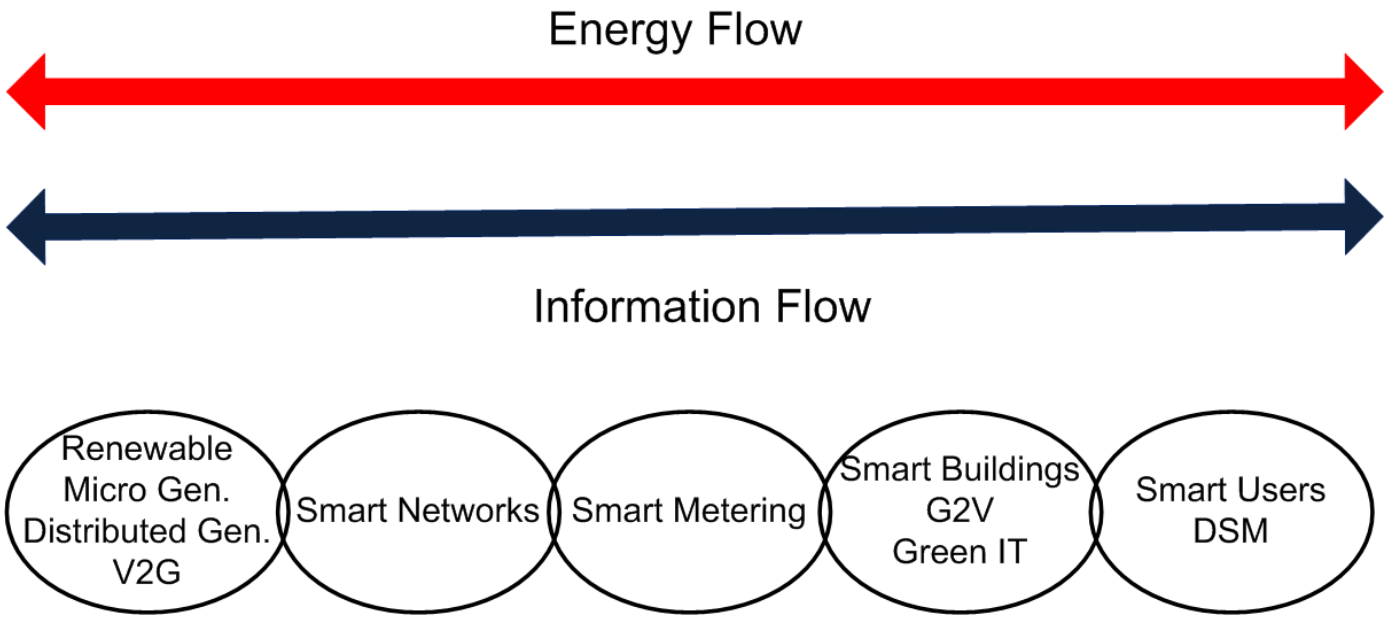
- Smartdust
  - US Military concept
    - Move to Nanotechnology
- Internet of Things
  - Expansion of Internet
  - 6LoWPAN
- Google's Android@Home
  - Device interoperability within the Home ..with android as glue

6LoWPAN

Arch Rock Corporation (2007) 'Arch Rock IP/6LoWPAN Overview: An IPv6 Network Stack for Wireless Sensor Networks'

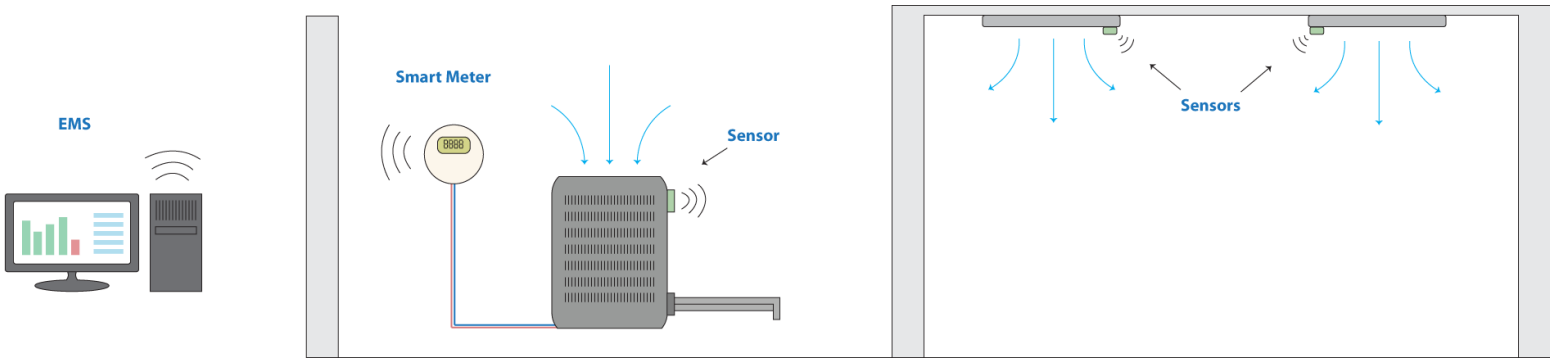


Recall SmartGrid



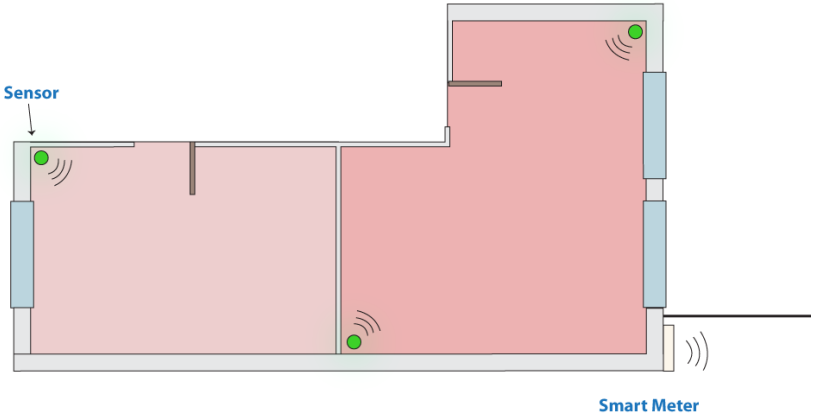
WSN Applications

- **Smart Grid : Smart Buildings - Industry**
  - **Smart meters** dispersed throughout building monitoring power flows
  - **Sensors** measuring air flow, temperature,CO2, occupancy etc.
  - **EMS** (Energy Management System) : Data along with real time pricing information used to drive DSS and schedule an efficient energy plan



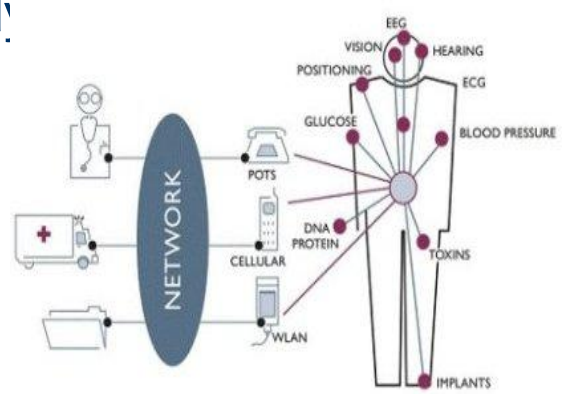
WSN Applications

- **Smart Grid : Smart Buildings -home**
  - **Smart Meter** – energy usage
    - Access to real time pricing ?
  - **Sensors** - measuring temperature, light, humidity,occupancy
  - **EMS** with **mobile interface** – Web app or mobile app used to monitor and schedule energy plan, V2G technology



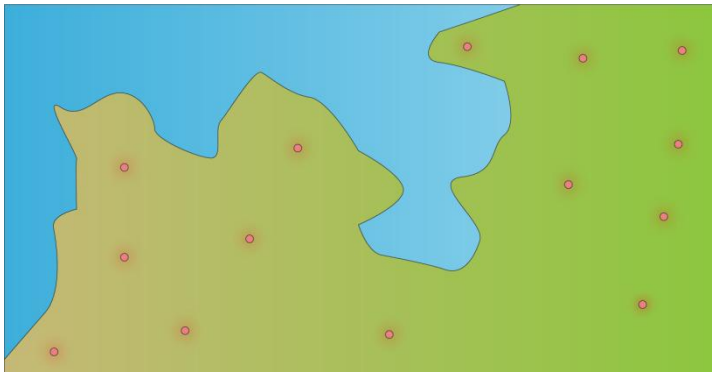
WSN Applications

- **WBAN (Wireless Body Area Network)**
  - Sensors measure vital parameters of body
  - Data transmitted over network
  - Analysis of multiple vital parameters
  - Better evaluation of condition
    - Delivered at reduced costs



WSN Applications

- **Environmental Monitoring**
  - Sensors dispersed over large geographical area
  - Acquire environmental data in real-time
- **Applications**
  - Flood management
  - Agricultural: Irrigation & nutrient systems
  - Weather forecasting
  - Air & Water quality



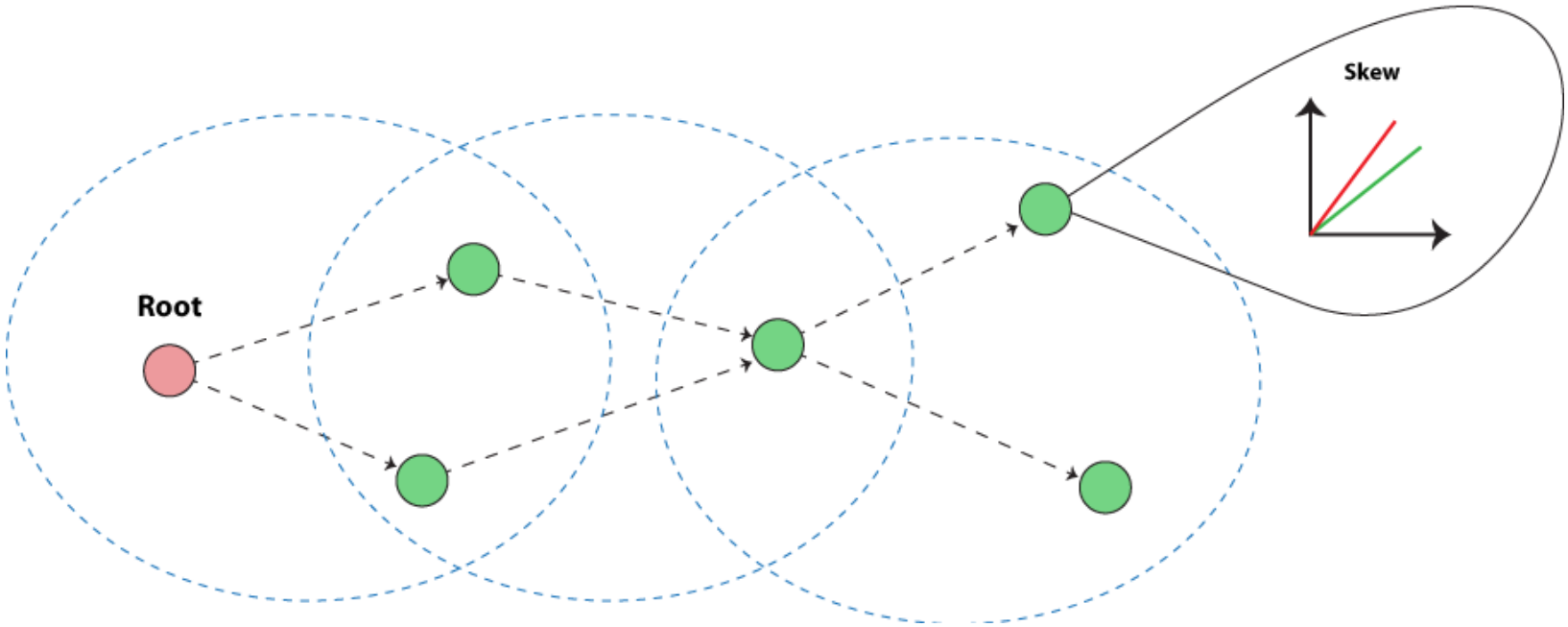
WSN Synchronisation

- **WBAN (Wireless body Area network)**
  - Multiple vital parameters
  - Require precise time alignment (< msec)
- **Environmental analysis**
  - Sensors are dispersed over large geographical area
- **Smart-Grid**
  - Time-stamped data used in conjunction with real-time pricing to formulate energy schedule
- ***NTP/PTP – significant computation & data transmission overhead***

Flooding Time Synchronisation Protocol (FTSP)

- Achieve accuracies of up to a 1 μs
- Operation –
  - **Root elected** based on lowest network ID
  - Root **broadcasts** time messages at **preconfigured tx interval**
  - Children use messages & regression analysis to determine **offset** and **skew**
  - Children begin broadcasting messages and process repeats

FTSP

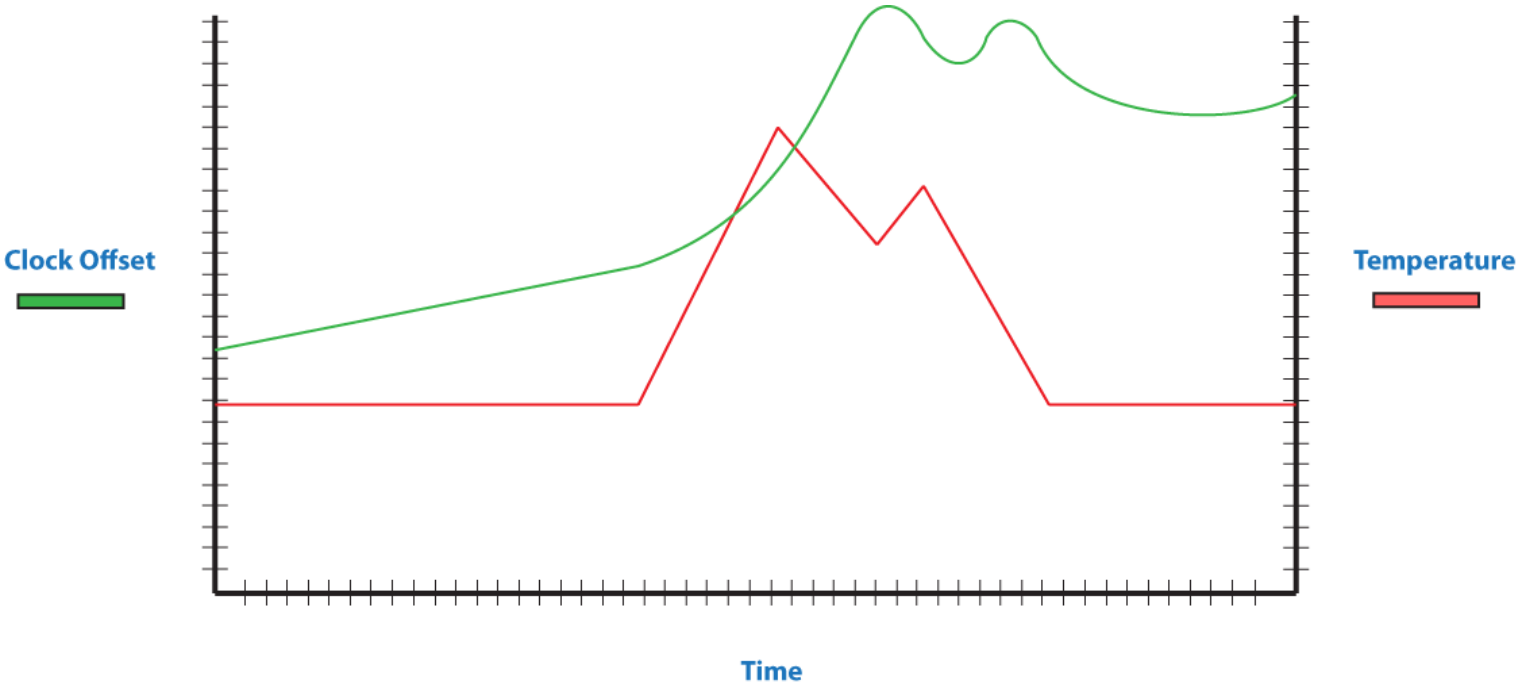


H. Melvin, ITSF, Nov. 2011

FTSP Issues

- **Directly** corrects for **skew** differences
- **Indirectly** correct for **drift** by pre-configuring a node's **tx** interval based on **worst case** future operating environment
- **Drift** – caused predominantly by temperature
- In stable environment with infrequent temperature fluctuations
  - Unnecessary communication overhead
  - Needless energy use

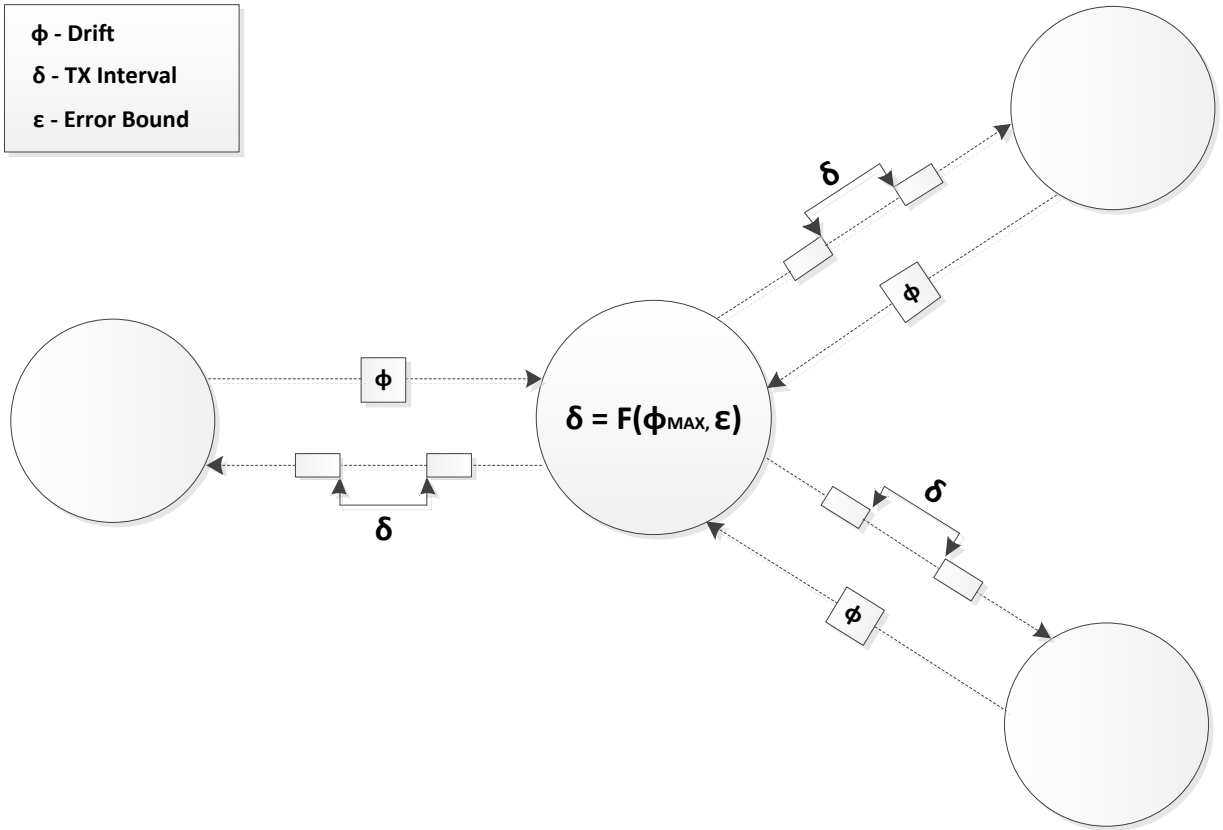
Temperature characteristic



Solution – D-FTSP

- Enhance FTSP to directly monitor drift
- Node alters **tx** interval based on both child's drift and an application error bound
- Optimise communication and therefore reduce energy use

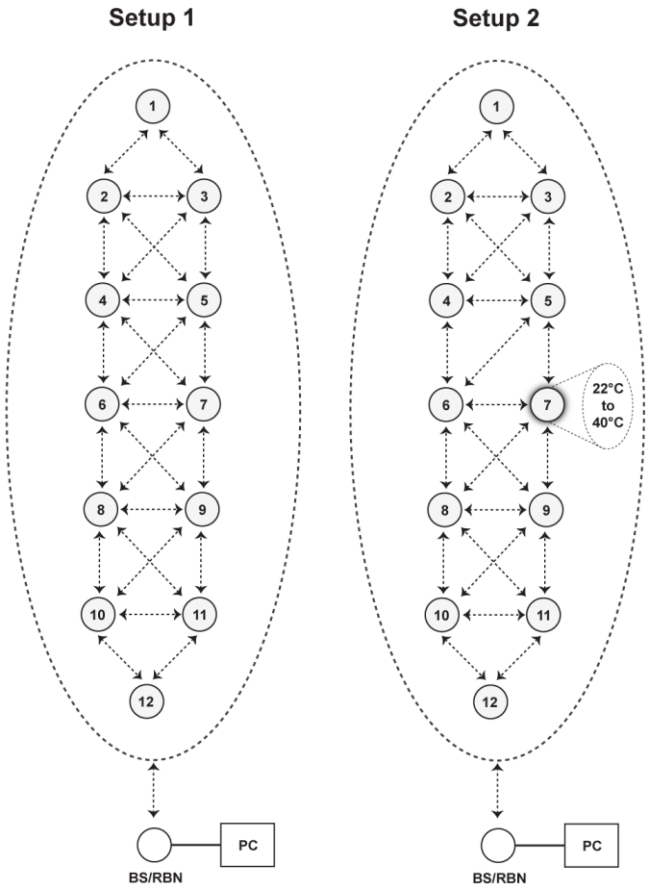
D-FTSP



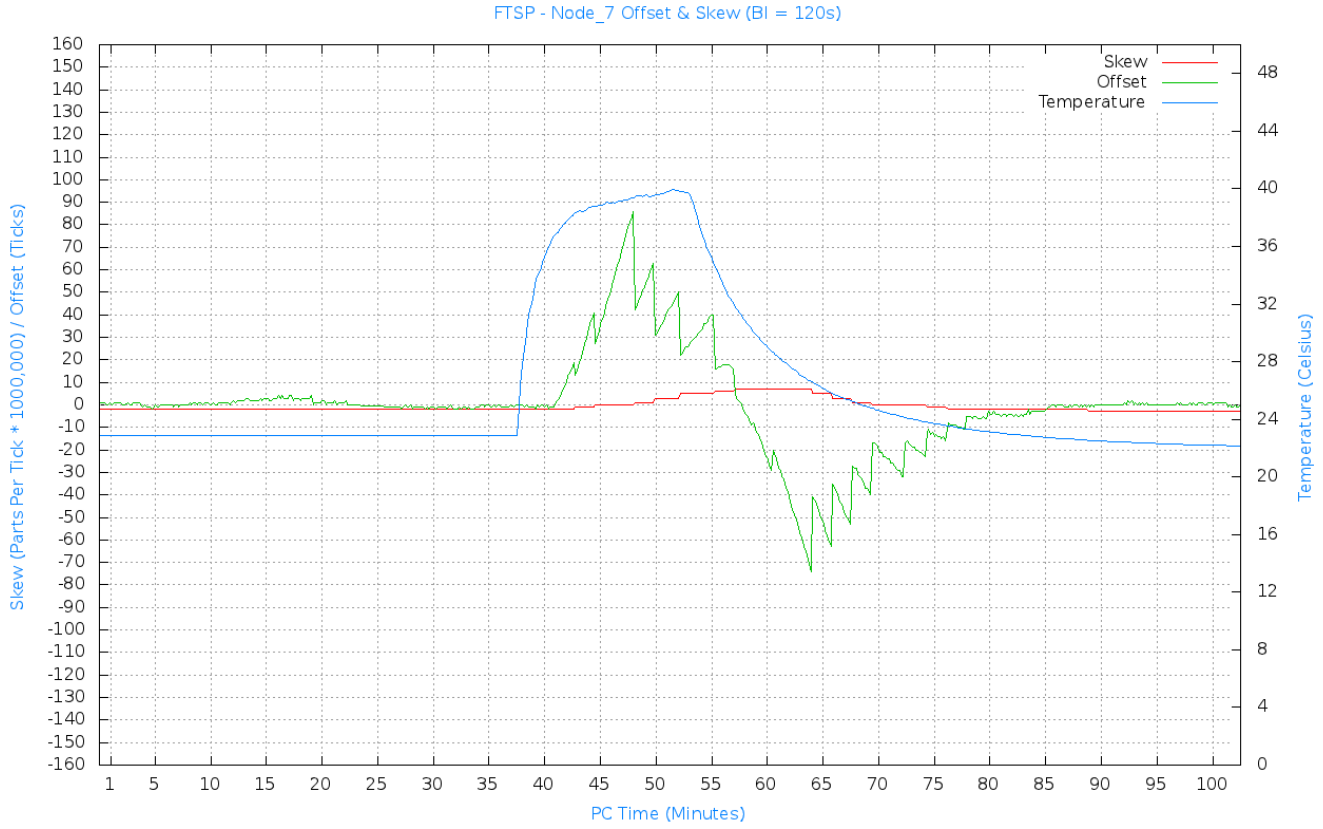
H. Melvin, ITSF, Nov. 2011

Experiments

- **Setup 1 –** Stable environment
- **Setup 2 –** Un-Stable environment
- **FTSP** with beacon intervals **30s**, **60s**, **120s** and **180s**
- **D-FTSP** with error bound of **1 tick**
- Experiment duration – **100** minutes



Results


FTSP - Node_7 Offset & Skew (BI = 120s)
Skew
Offset
Temperature
Skew (Parts Per Tick * 1000,000) / Offset (Ticks)
Temperature (Celsius)
PC Time (Minutes)

Results- Stable environment

FTSP

δ (s)	# Transmissions	Mean (Ticks)	Max (Ticks)	σ (Ticks)
30	2,400	1.15	8.00	1.17
60	1,200	1.21	8.00	1.24
120	600	1.29	7.00	1.22
180	400	1.52	9.00	1.36

DFTSP

εavg (Ticks)	# Transmissions	Mean (Ticks)	Max (Ticks)	σ (Ticks)
1	502	0.93	5.00	0.90

Results- Unstable environment

FTSP

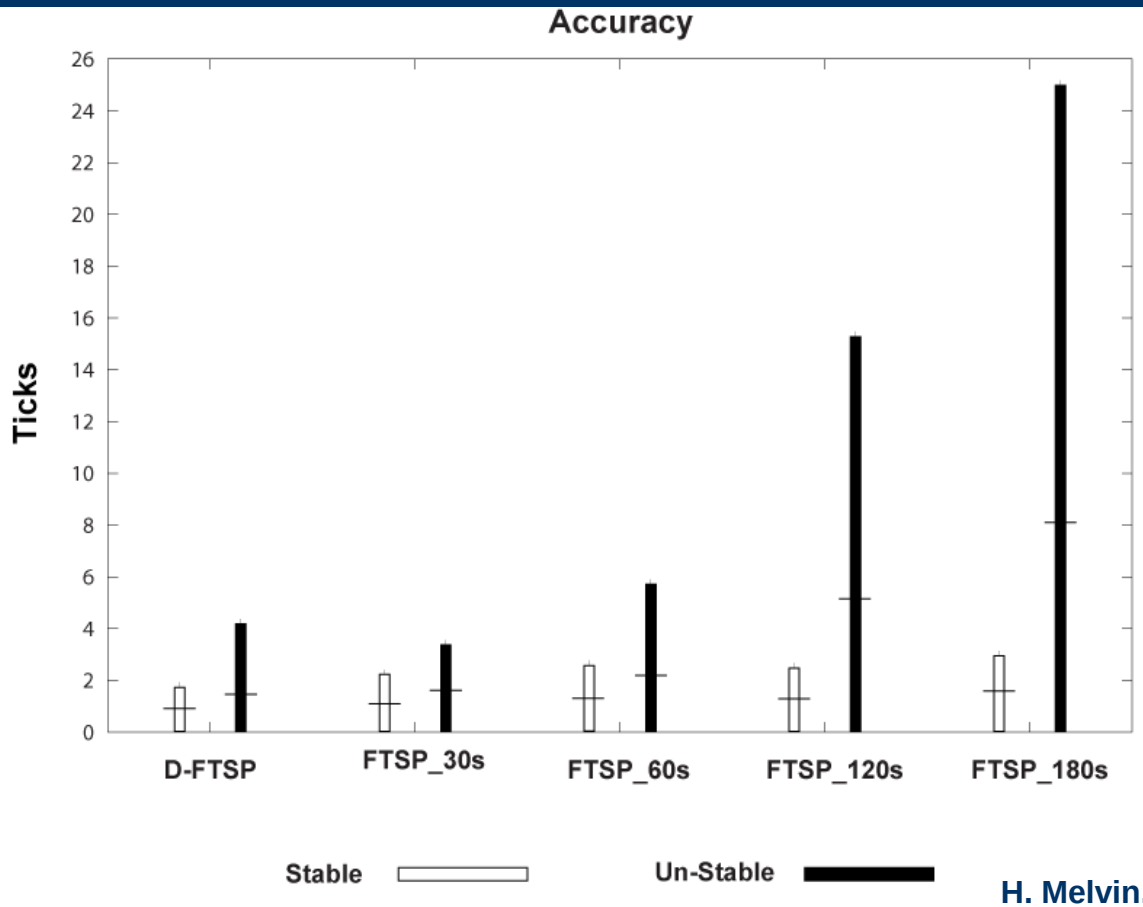
δ (s)	# Transmissions	Mean (Ticks)	Max (Ticks)	σ (Ticks)
30	2,400	1.61	17.00	1.78
60	1,200	2.18	29.00	3.57
120	600	5.18	86.00	10.16
180	400	8.12	156.00	16.90

DFTSP

ε_{avg} (Ticks)	# Transmissions	Mean (Ticks)	Max (Ticks)	σ (Ticks)
1	634	1.50	58.00	2.74

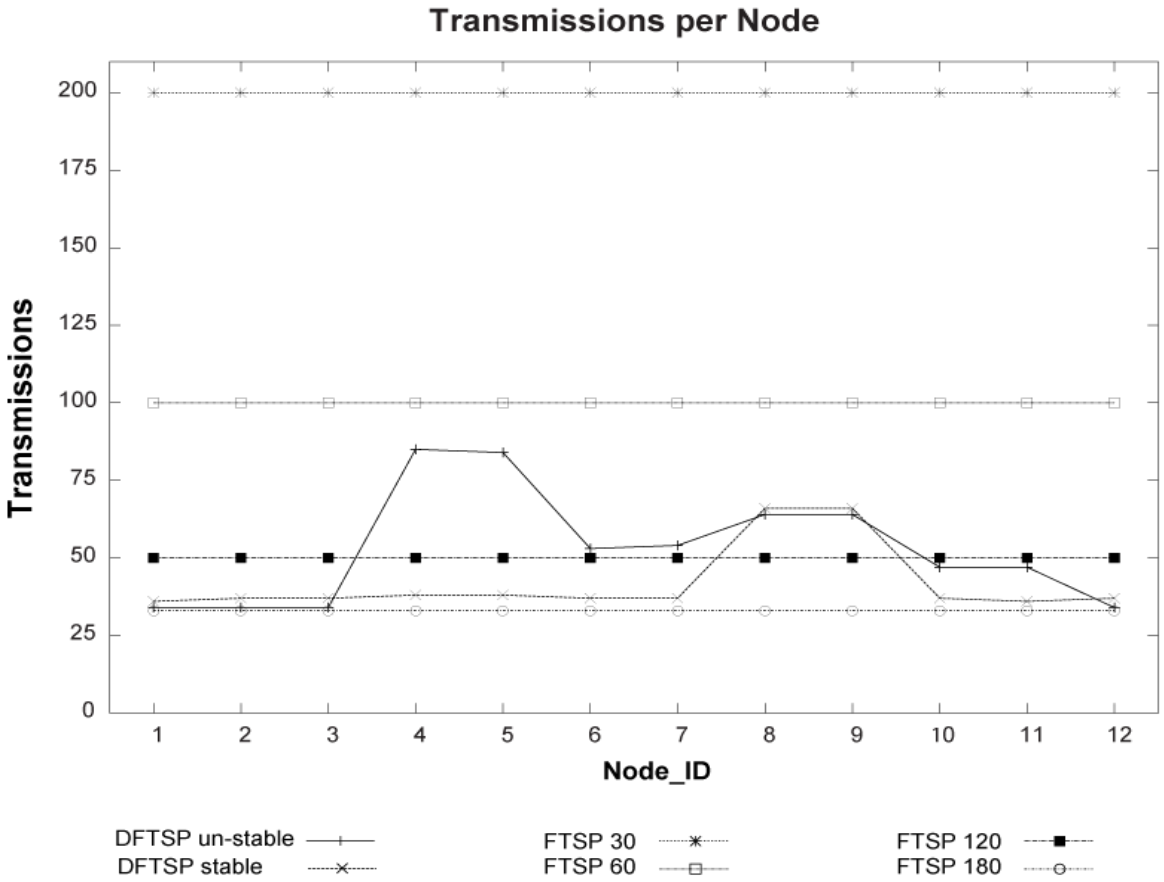
H. Melvin, ITSF, Nov. 2011

Results



H. Melvin, ITSF, Nov. 2011

Results


Transmissions per Node
Transmissions
200
175
150
125
100
75
50
25
0
1
2
3
4
5
6
7
8
9
10
11
12
Node_ID
DFTSP un-stable
DFTSP stable
FTSP 30
FTSP 60
FTSP 120
FTSP 180

Conclusions

- WSN market growth
  - Range of Application Domains
- Synchronisation requirements vary greatly
- Energy use key issue
  - Limit communication
  - Maximise sleep time
  - D-FTSP limits synchronisation overhead

I....Professor Maoldearga O Maolmisery ...have created the worlds first **quantum-computer powered WSN**

H. Melvin, ITSF, Nov. 2011

© Alex Bannykh * www.ClipartOf.com/36072

H. Melvin, ITSF, Nov. 2011