IReHMo: An Efficient IoT-based Remote Health Monitoring System for Smart Regions

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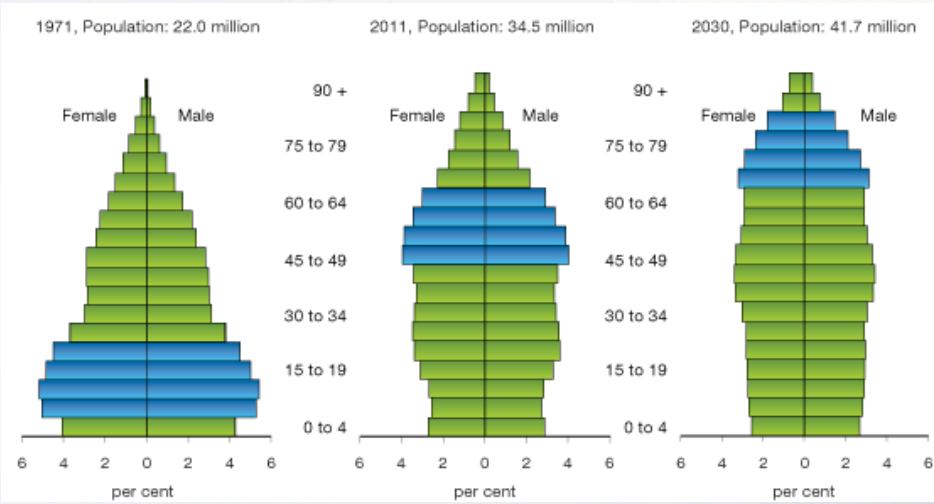
Agenda

- The context
- Research question, challenge and major contributions
- The base-line eHealth system
- The proposed architecture
- Results
- Summary, conclusion & future works

The context: Elderly population

- Elderly people take a big portion in the population
  - » Over the world: 7 %
  - » In whole Sweden: 19.6 %
  - » In Västerbotten region: 20.4 %
  - » Some communities in Västerbotten: 24.7 %, 27.6 % and 30.7 %
- Healthcare facilities for elderly people: home care, hospitals, health center, home for elderly people



Age structure of Canada

The context: Elderly population

- Home care is the prefered choice [1]
- The cost for traditional homecare is enormous*
- Remote sensors, IoT devices can help
- Cost is significantly reduced*
- Part of the Smart city and Smart region paradigm

*: **Tomorrow's cities: Sensor networks for the elderly @BBC< http://www.bbc.com/news/technology-22984876 >**

The context: Internet of Things

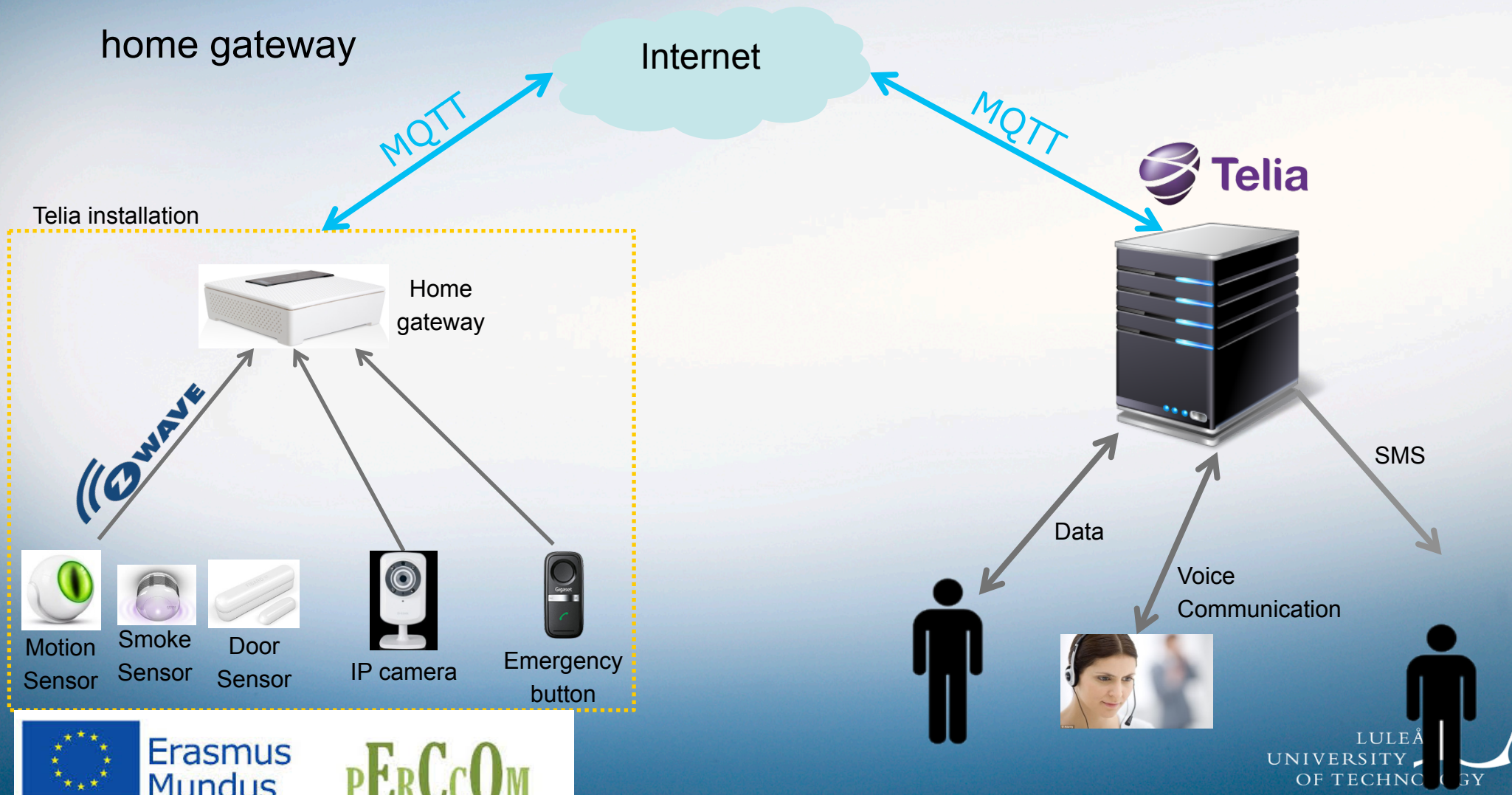
- IoT is a key enabler, presenting in many fields, including **healthcare**
- A motivating scenario:
  - » An elderly person staying at home
  - » Devices to monitor environment parameters, to send alarms, to automate lighting and HVAC tasks
  - » Healthcare devices: to monitor body parameters, to detect patterns and activities
  - » Camera to have live video from the house
- Remote health monitoring system depends on the communication network

The research challenge

- Research question
  - » How efficiently and securely transmit healthcare data within the limit of existing network infrastructure?
- Research challenge
  - » How to handle this for infrastructure for both urban and rural areas?
- Major contributions of the paper
  - » To study the network communication requirements
  - » To propose an overall remote health monitoring architecture
  - » To realize the architecture into a prototype that makes significant reductions (volume of generated data, required bandwidth) compared with an existing commercial product

The base-line eHealth system

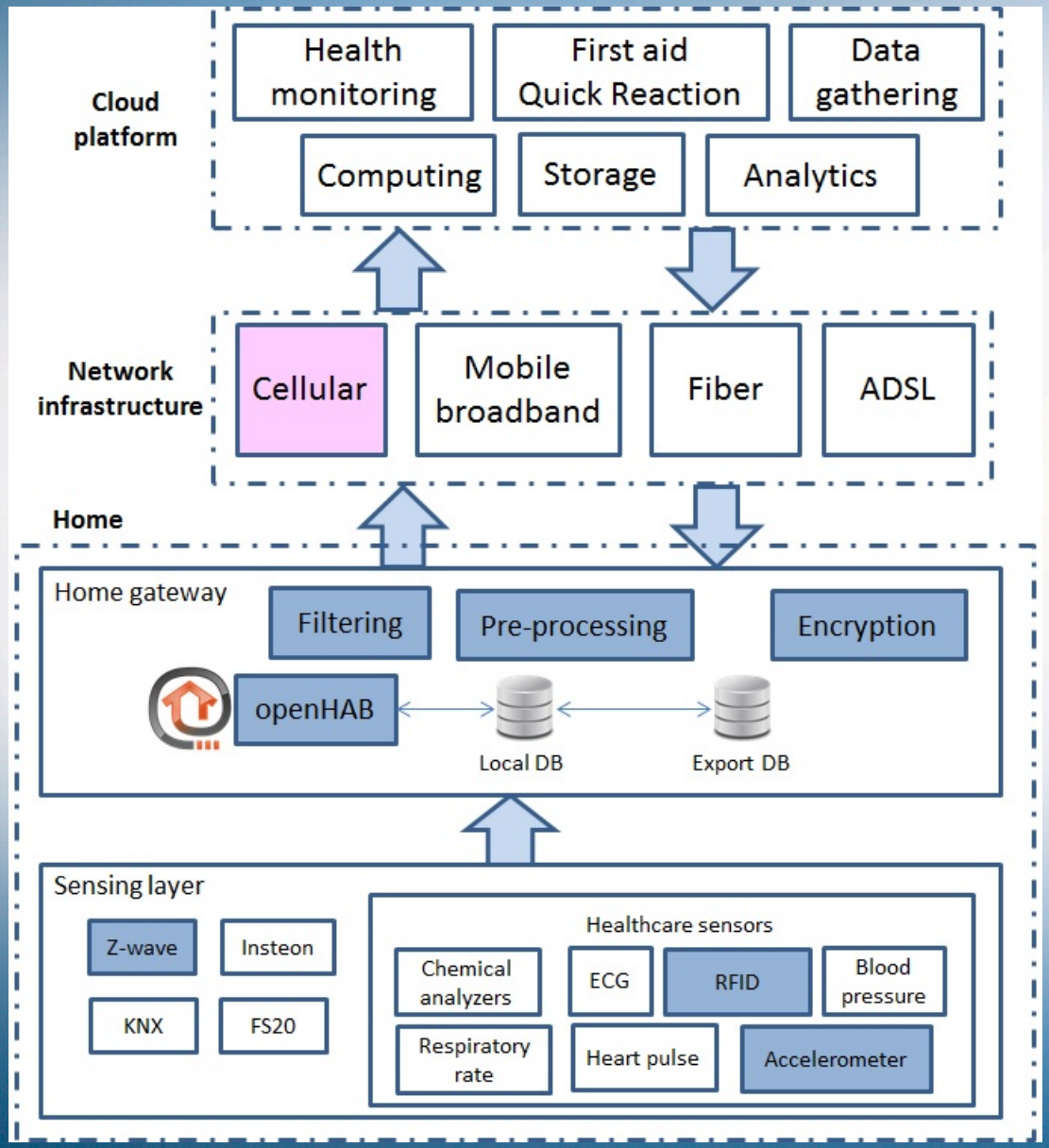
- The system consists of various sensors, emergency button, IP camera and a home gateway



The base-line eHealth system

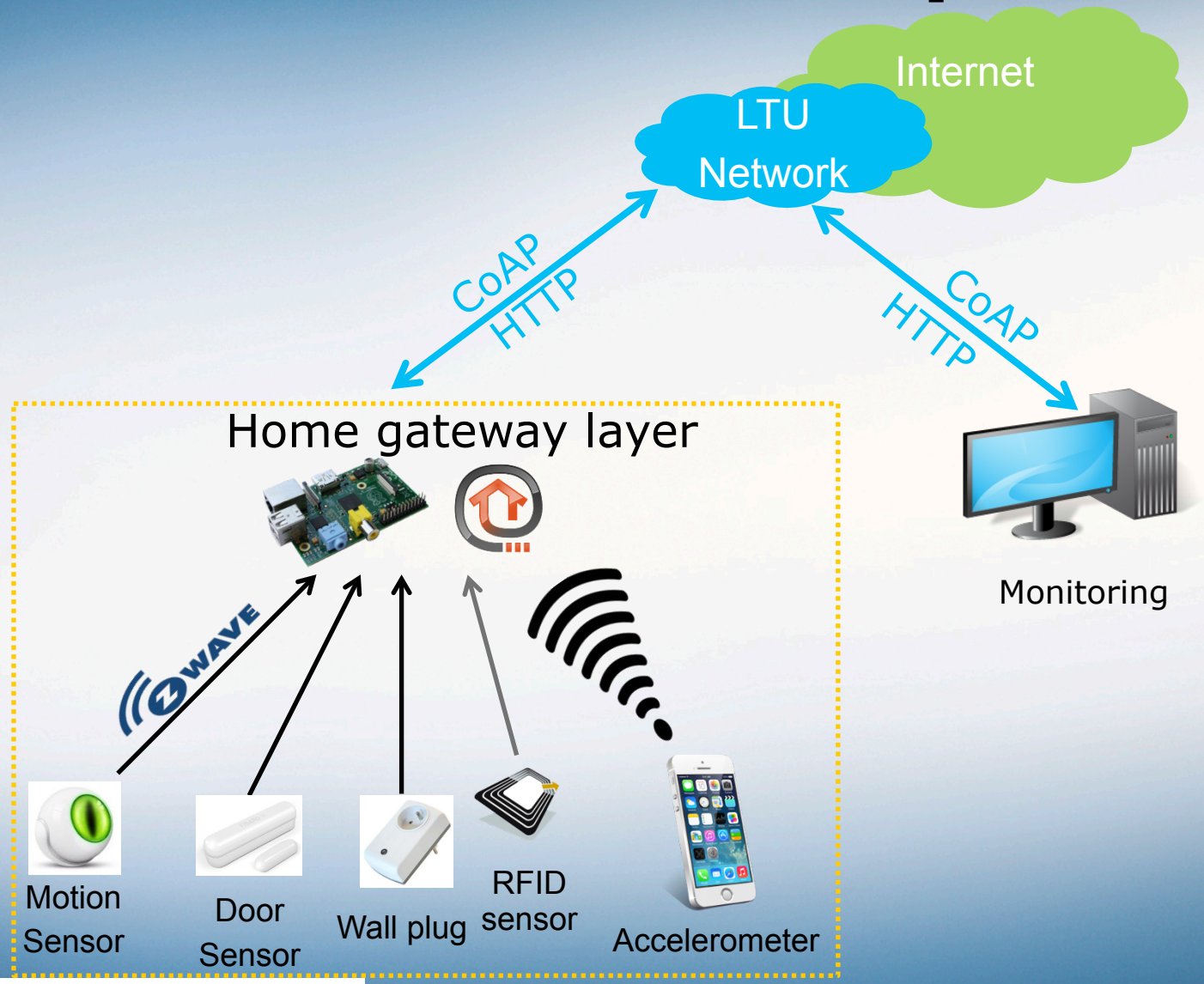
- Capabilities of the Telia system
  - » Update the events to the remote servers in real-time
- Shortcomings of the Telia system
  - » Proprietary system
  - » Not efficient in terms of bandwidth and data

The proposed architecture



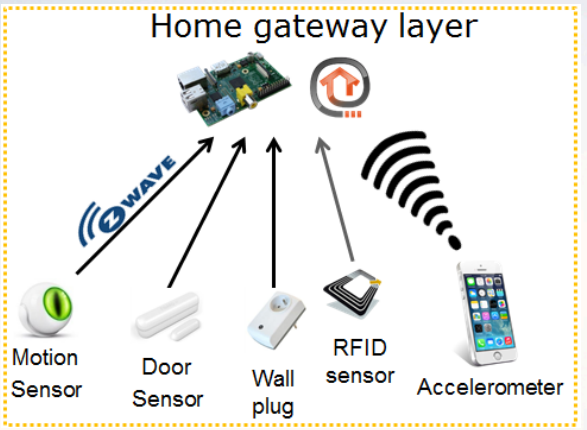
IoT-based remote health monitoring system - IReHMo

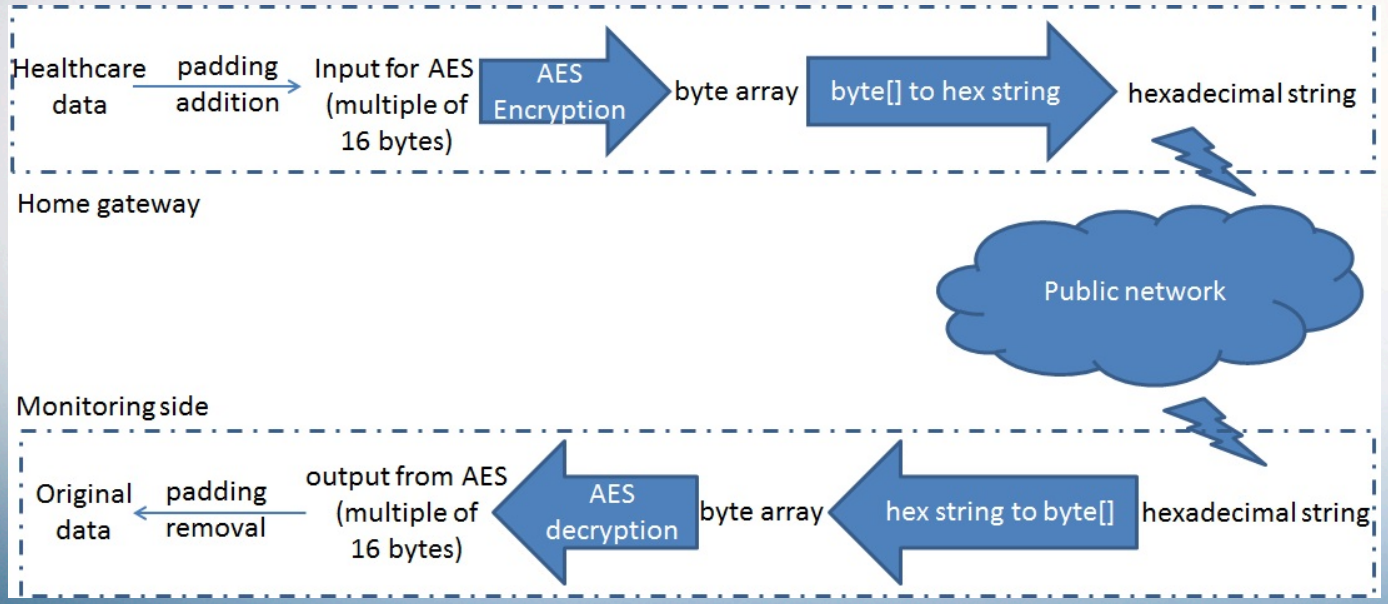
The IReHMo implementation



The IReHMo implementation

- Pre-processing & filtering:
  - » Not all the raw data needs to be sent
  - » Reduce bandwidth and volume of generated data
- Encryption



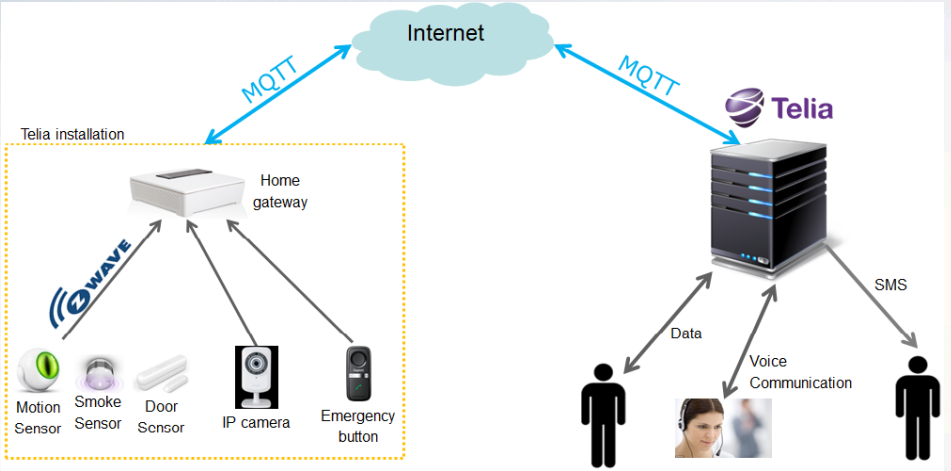


The results

- The measurements from the existing eHealth system
- The measurements from the IReHMo prototype
- The bandwidth requirements from healthcare scenarios
- The scalability analysis
  - » Demographic information
  - » Network capacity

The results – existing eHealth system

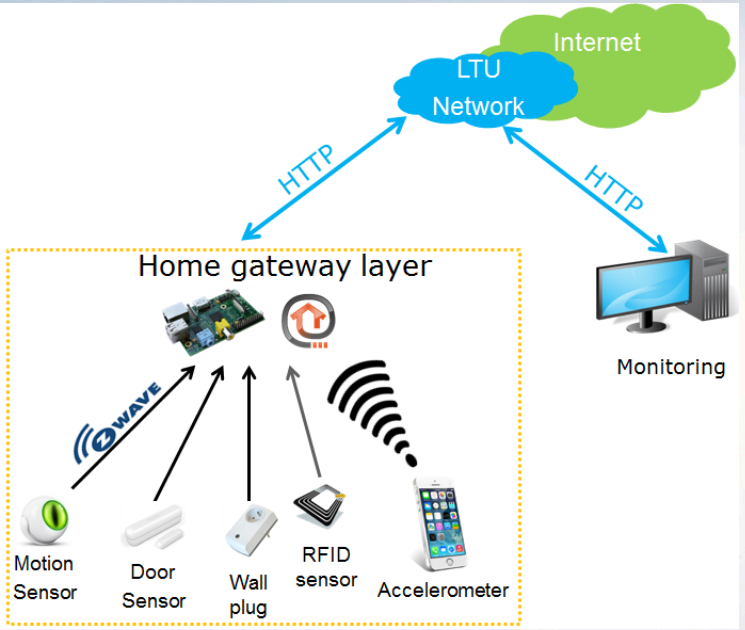
- The Telia system:
  - » MQTT protocol for delivering sensor data
  - » Periodic traffic pattern
  - » Sensor traffic pattern
    - Several packets per event
    - Each packet is acknowledged



Event	Bytes (uplink/downlink)	Bytes (total)	Bitrate in kbps (uplink/downlink)
Door open	556 / 280	836	4.448 / 2.24
Smoke alarm ON	890 / 420	1310	7.12 / 3.36
Wall plug ON	636 / 280	916	5.088 / 2.24
Video frame			167.46 / 12.328
Voice connection			32 / 32

The results – IReHMo with HTTP

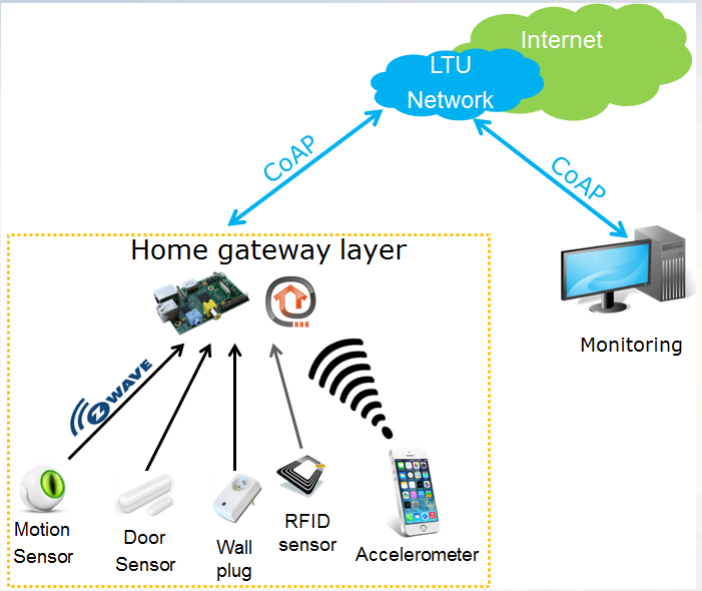
- HTTP-based IReHMo implementation
  - » Using HTTP GET method
  - » HTTP session
  - » 3-way handshake, request/response, TCP Keep-Alive, session closing



Event	Bytes (upload/download)	Bytes (total)	Bitrate in kbps (upload/download)
Request/response	188 / 359	547	1.504 / 2.872
Whole session	494 / 845	1339	

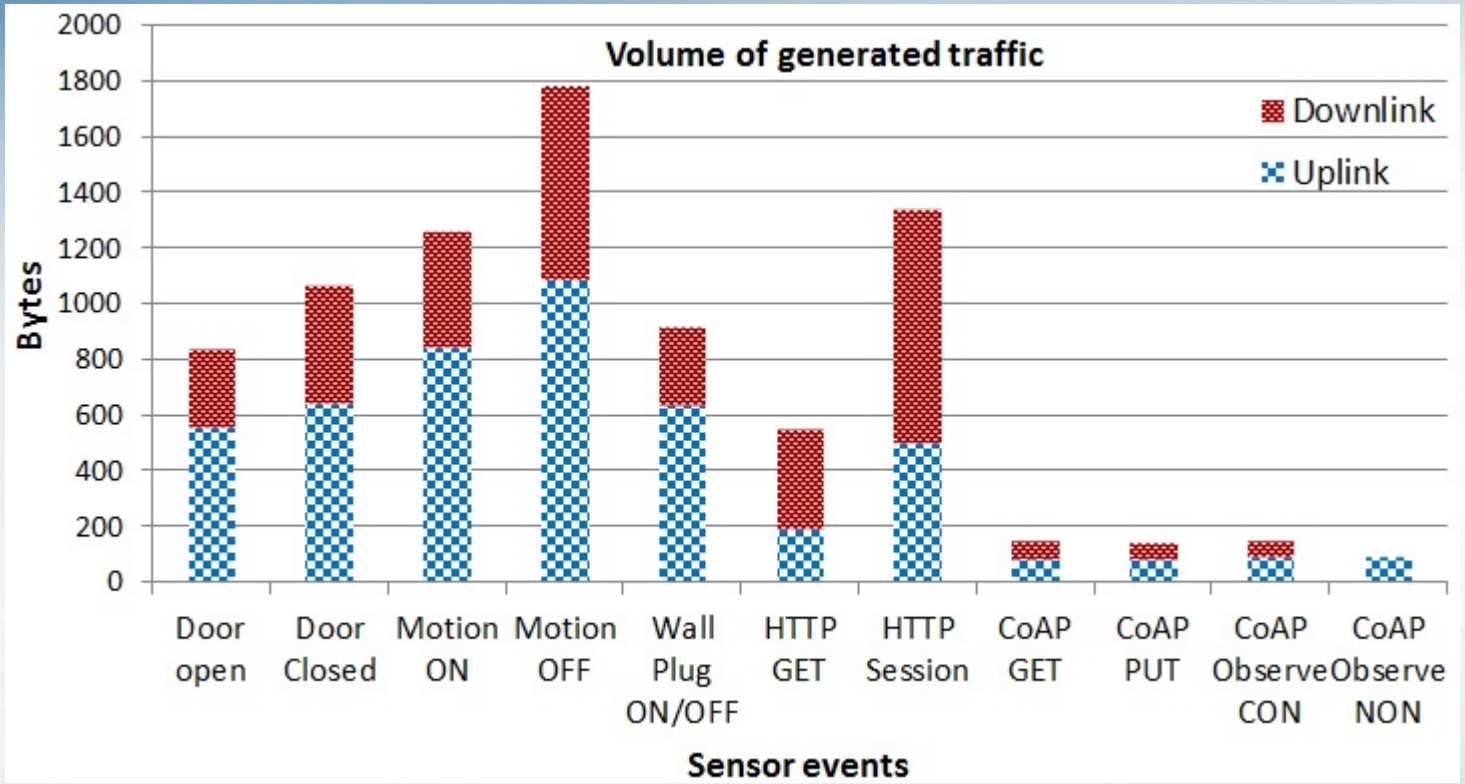
The results – IReHMo with CoAP

- CoAP-based IReHMo implementation
  - » Get a sensor value: GET, PUT, Observe
    - GET, PUT: request/response
    - Observe: Gateway continuously informs the client
  - » QoS mechanisms: CON and NON



CoAP method	Bytes (upload/download)	Bytes (total)	Bitrate in kbps (upload/download)
GET (CON & NON)	82 / 60	142	0.656 / 0.48
PUT(CON & NON)	80 / 60	140	0.64 / 0.48
Observe CON	85 / 60	145	0.68 / 0.48
Observe NON	85 / 0	85	0.68 / 0

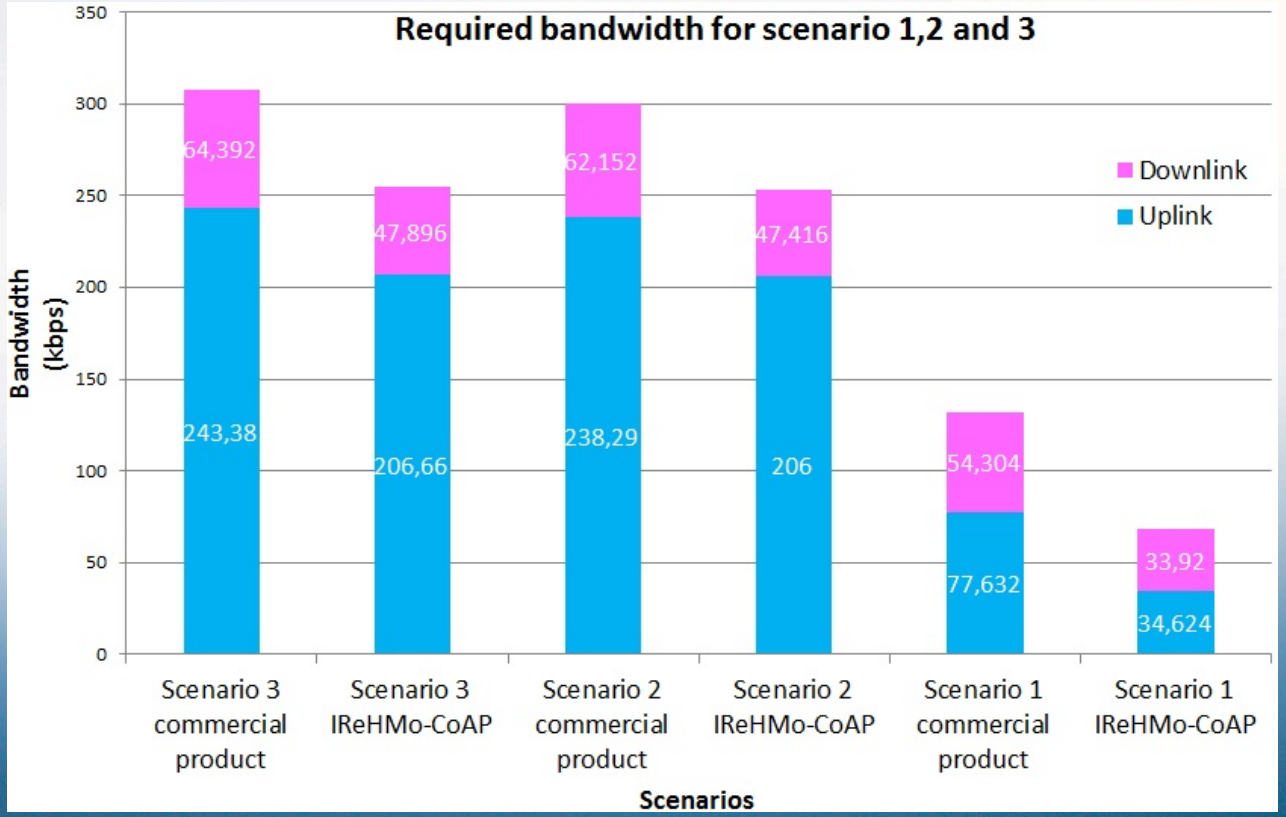
The results - Comparisons



- CoAP is the most efficient protocol
  - » Volume of traffic
  - » Bandwidth
  - » Number of packets

The results - Scenarios

Name	Components
Scenario 1	Emergency button, 2 power plugs, motion sensor, IP camera
Scenario 2	Emergency button, power plug, motion sensor, IP camera
Scenario 3	Emergency button, door sensor, motion sensor, fire alarm



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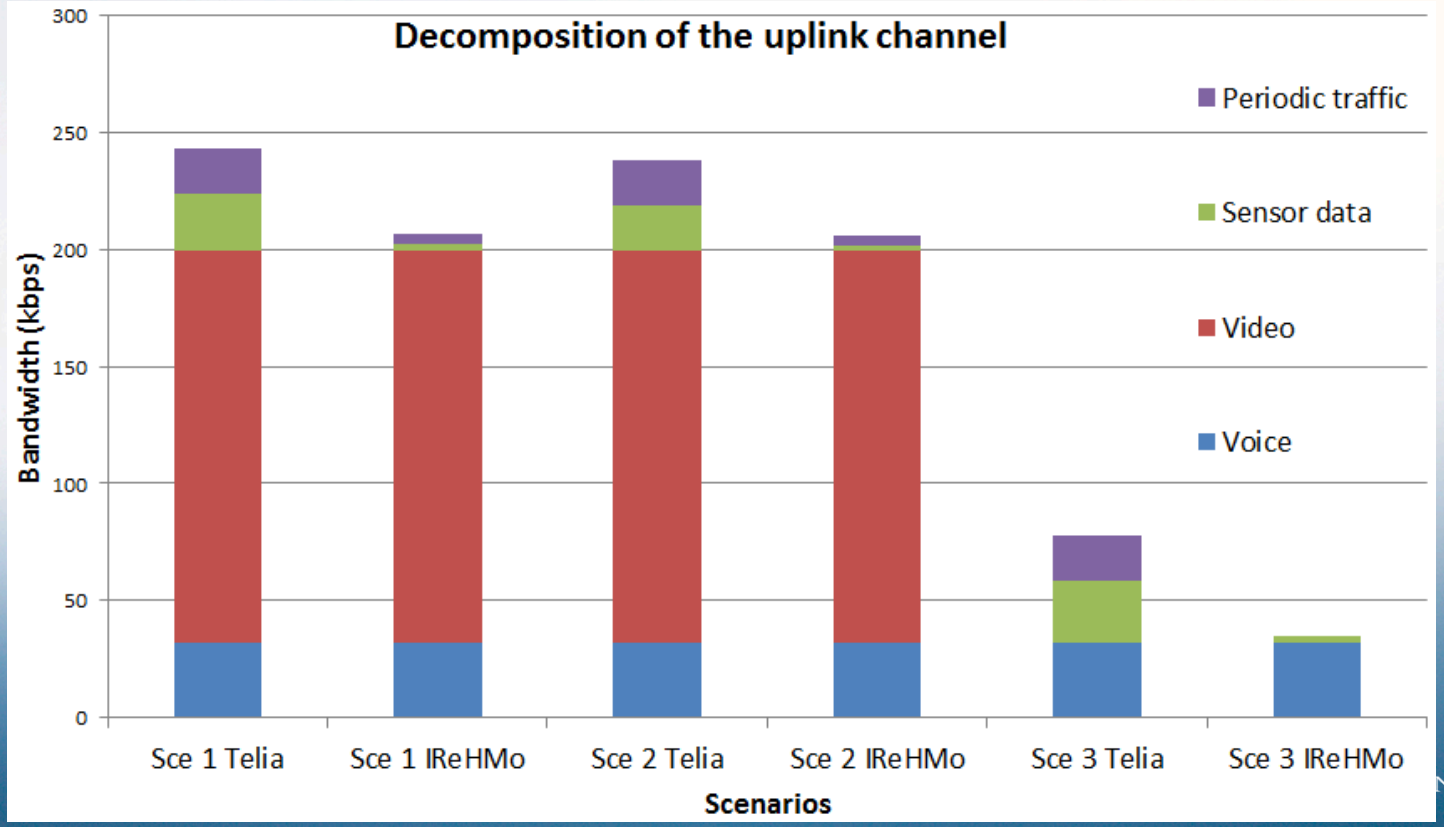
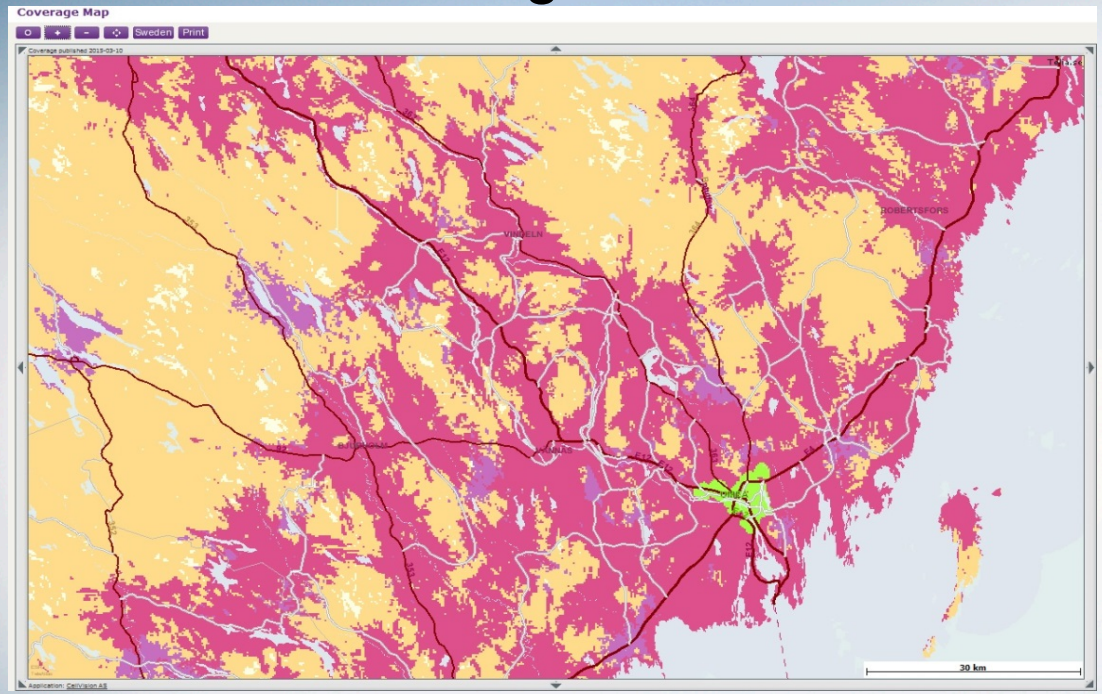


Scalability analysis

- Demographic information
- Network infrastructure
  - » Coverage map
  - » Network categories (DC-HSPA+, LTE, LTE-Advanced)
  - » Available bandwidth
- Assumption
  - » The worst-case scenario
  - » All the network capacity is dedicated for healthcare traffic

Scalability analysis - Network information

- Indoor coverage



Network category	
EDGE	
Turbo-3G	
Turbo-3G+	
4G	
4G+	

- Turbo-3G+ corresponds to DC-HSPA+
- Need to know the practical bandwidth, cell capacity in the uplink

Scalability analysis - Network information

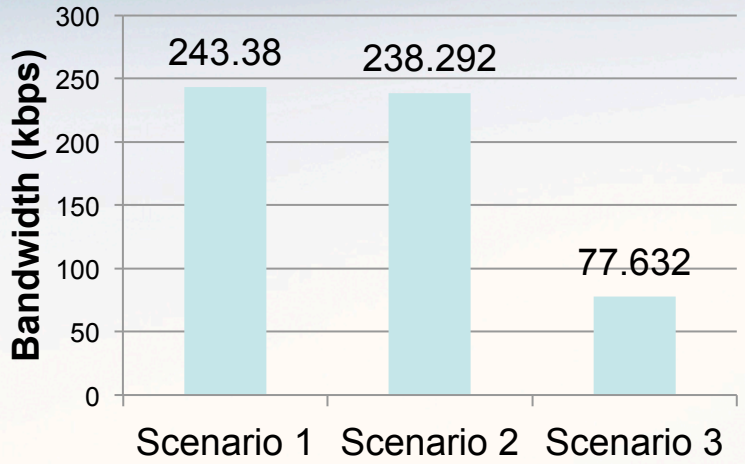
- Measuring the real available bandwidth

Location	Upload bandwidth	Download bandwidth
Gumboda	2.13 – 3.61 Mbps	8.15 – 9.22 Mbps
Renström	2.19 – 2.67 Mbps	11.68 – 13.96 Mbps
Bastuträsk	1.35 – 2.45 Mbps	12.20 – 15.36 Mbps

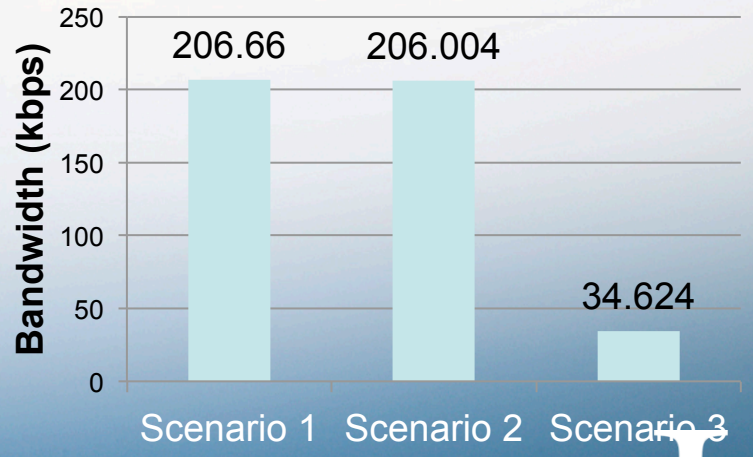
- Cell capacity in the uplink channel: 6.2 Mbps [6]

Scalability analysis

Villages	Elderly / Population	100% scenario 1	30-40-30	10-20-70	100% scenario 3	Available bandwidth
Gumboda	13 / 55	3,34	2,63	1,73	1,06	6.2 Mbps
Renström	17 / 67	4,07	3,20	2,11	1,30	6.2 Mbps
Långträsk	27 / 109	6,63	5,22	3,44	2,11	6.2 Mbps
Moskosel	58 / 232	14,11	11,11	7,32	4,50	6.2 Mbps
Bastuträsk	98 / 392	23,85	18,77	12,38	7,60	6.2 Mbps
Backe	150 / 599	36,44	28,69	18,91	11,62	6.2 Mbps
Jörn	199 / 797	48,49	38,18	25,17	15,46	6.2 Mbps
Junsele	200 / 800	48,67	38,32	25,26	15,52	6.2 Mbps
Boliden	391 / 1566	95,28	75,01	49,46	30,39	6.2 Mbps



		100% scenario 1	30-40-30	10-20-70	100% scenario 3	Available bandwidth
Gumboda	13 / 55	2,84	2,12	1,18	0,47	6.2 Mbps
Renström	17 / 67	3,46	2,59	1,44	0,57	6.2 Mbps
Långträsk	27 / 109	5,63	4,21	2,34	0,94	6.2 Mbps
Moskosel	58 / 232	11,98	8,97	4,99	2,00	6.2 Mbps
Bastuträsk	98 / 392	20,25	15,16	8,43	3,39	6.2 Mbps
Backe	150 / 599	30,94	23,17	12,89	5,18	6.2 Mbps
Jörn	199 / 797	41,17	30,84	17,15	6,89	6.2 Mbps
Junsele	200 / 800	41,33	30,95	17,22	6,92	6.2 Mbps
Boliden	391 / 1566	80,90	60,59	33,70	13,55	6.2 Mbps



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Summary, Conclusion and future work

- The requirements of a base-line eHealth-monitoring system is identified considering:
  - » Network requirements
    - Consume low bandwidth
    - Generate small amount of data
- Design and implementation of an overall system architecture (IReHMo)
- CoAP-based IReHMo significantly reduces the volume of data and bandwidth requirement (up to 90% volume of generated data, 56% of required bandwidth)
- Analyze the scalability of the system

Summary, Conclusion and **Future work**

- Study in details different healthcare type of data
  - » Non-time-critical: Body temperature, blood pressure, …
  - » Time-critical: ECG signal

- Improve the reliability of the net work communication

- Incorporate activity recognition to precisely detect the state of the patient [3]

Key reference

- [1]: T. Bengtsson, Population Ageing-a Threat to the Welfare State?: The Case of Sweden. Springer Science & Business Media, 2010.

- [2]: M. Valtonen. (2010, March) The bitrate limits of hspa+ enhanced uplink. [Online]. Available: http://omnitelecom.s3.frantic.com/2011/05/the_bitrate_limits of_hspa_enhanced_uplink.pdf

- [3]: S. Saguna, A. Zaslavsky, and D. Chakraborty, “Complex activity recognition using context-driven activity theory and activity signatures,” ACM Transactions on Computer-Human Interaction (TOCHI), vol. 20, no. 6, p. 32, 2013.