The In and outs of Wireless Audio

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Background

- Joined APT in 1994 as development engineer.
- Led the MBO in 2005 and the introduction of IP licensing within APT,
- Split Hardware and Licensing into 2 separate business units in 2009.
- Sold Hardware business to Audemat in 2009.
- Sold APT Licensing to CSR in 2010.
- Responsible for CSR aptX audio compression rollout.

CSR Background

- Founded 1999
- Bluetooth, Wifi, GPS, FM radio technologies.
- Kalimba DSP platform.
- Fabless semiconductor design company.
- Acquired SIRF in 2009 for GPS
- Acquired aptX in Belfast in Aug 2010
- Around 3000 people with Zoran merger
- $800M revenue (2010)

Introduction

- Why is audio important for wireless devices?
- Bluetooth – a typical wireless use case.
- The implications on codec selection.
- Latency and wireless audio.

Why is audio important for wireless devices?

- Audio is one of the most common forms of data transferred between portable devices
  - ~ Speech is an obvious use case
  - ~ Music is becoming more popular
- Wireless ecosystems are becoming more complex
  - ~ Multiple simultaneous links between devices.
  - ~ Games console, phone, headset, controllers.
  - ~ A connectivity centre for multiple use cases.

Wireless overview

- Different forms of audio streaming using a wireless link...
  - Broadcast (e.g. Digital Radio)
  - On demand listening (e.g. Spotify)
  - Cellular conversations (e.g. Mobile phone)
  - Multi-room music distribution (e.g. Sonos, Airplay)
  - Ultra low latency streaming (e.g. Microphones)
  - Personal music network (e.g. Bluetooth)

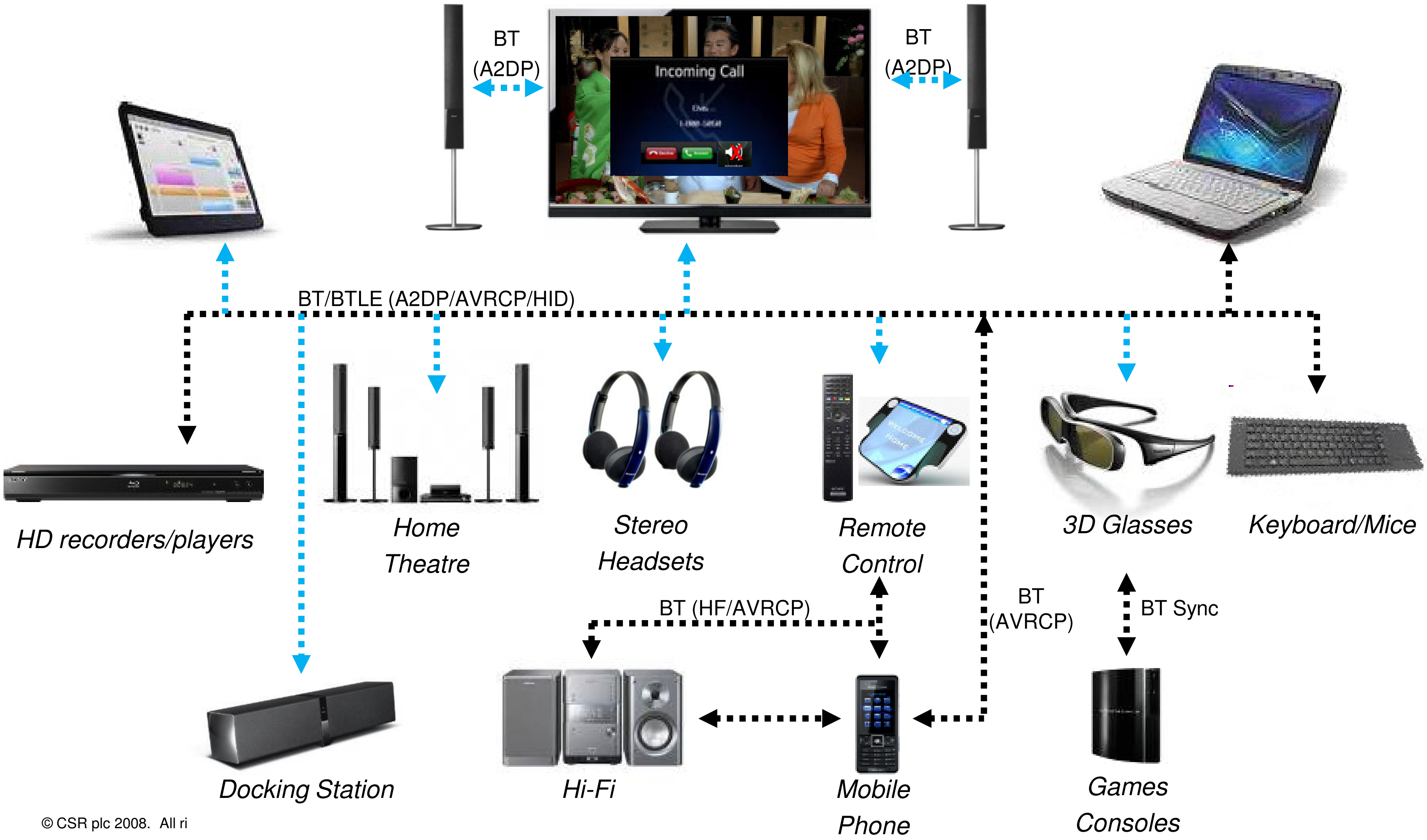
Two tier distribution

Wide

Local

Broadcast...

Local ecosystem



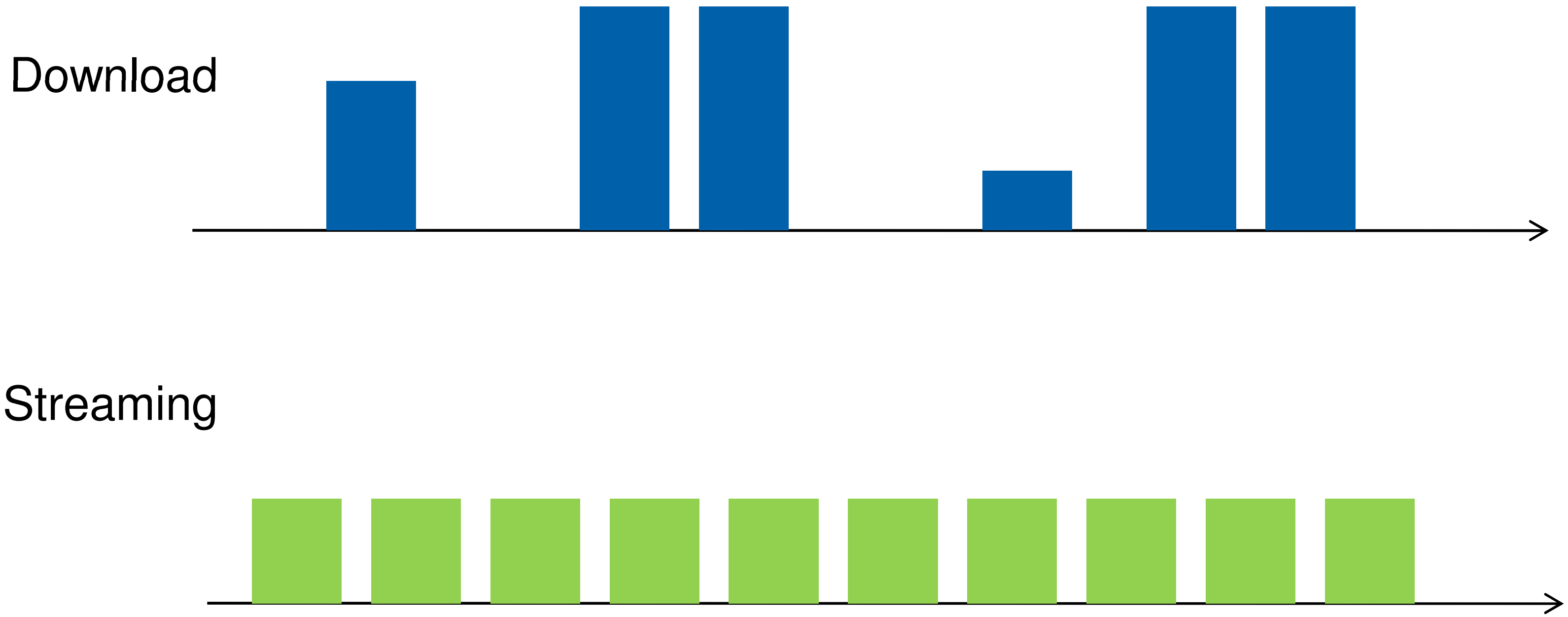
Wireless audio definition...

- Local streaming
- Multiple connections
- Overlap with wider networks
- Distinct requirements
- Voice and music

Music streaming...

Streaming or downloading?

- Do we want a continuous stream with low latency or a fast and efficient method of transferring the data?

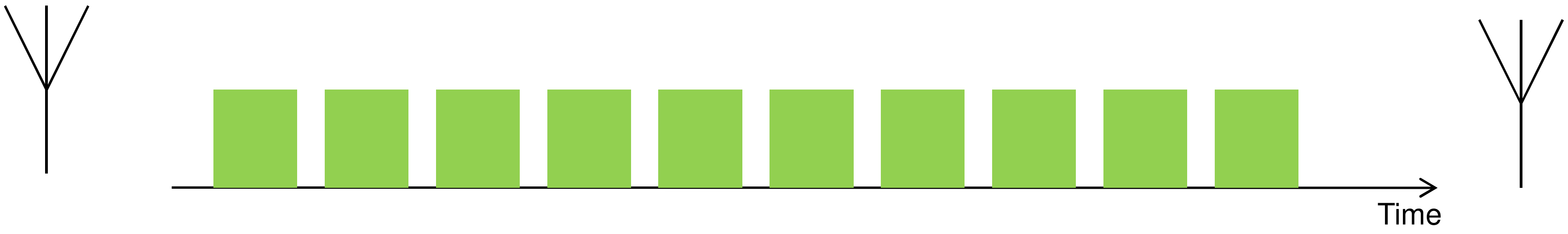


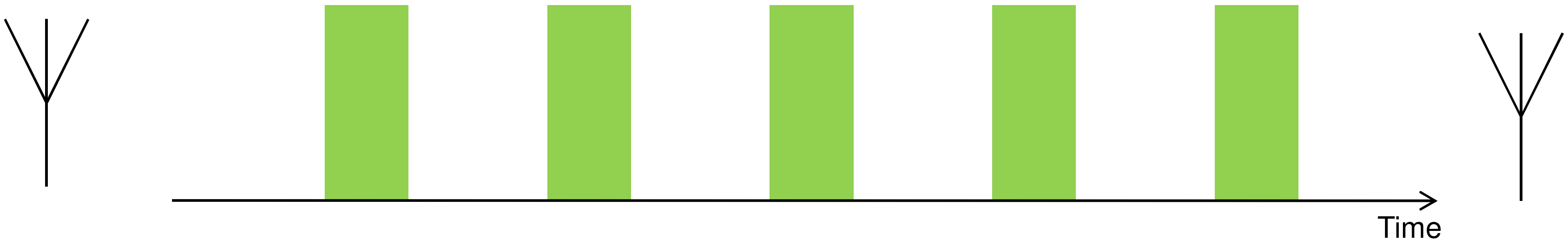
Wire replacement

- Audio quality is defined “as good as a wire”.
  - Just use PCM?
- Ideal solution:
  - Zero power consumption
  - Perfect audio quality
  - Zero latency
  - Very low cost… (cable is cheap)
  - Has value add – passive to active

General data transfer

Streaming





Why do we need codecs?

- Efficient transfer of audio data is essential
  - ~ Bandwidth limitations
- This affects:
  - ~ Complexity
  - ~ Battery life
  - ~ Perceived audio quality
  - ~ Latency
  - ~ Transcoding effects
  - ~ Cost…

Coding for wireless transfer

- The codecs that are part of the Bluetooth A2DP specification are based on existing audio compression codecs.
- These are targeted for **storage**, such as MP3, AAC, WMA etc.
- Primary tradeoff is data rate/compression/complexity against audio quality.
- Encoders can be substantially more complex than decoders.
- Wireless transfer requires a different set of parameters to be considered…

Coding for wireless transfer

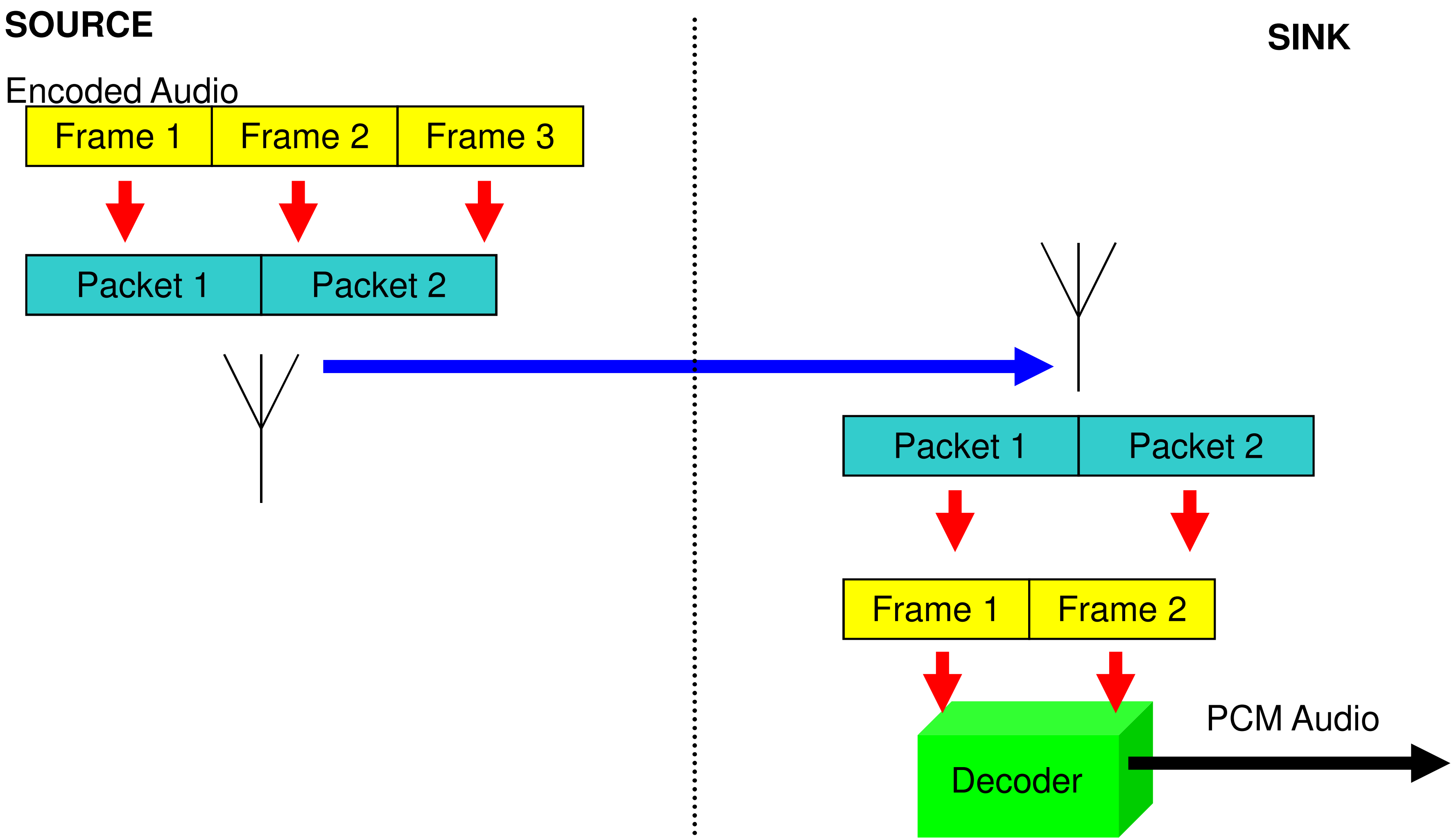
- A wireless audio stream has inherent latency.
- The combination of the audio codec and the wireless stream protocol must maintain low latency.
- Data rate, compression, complexity and audio quality are still important.
- Encoder and decoder should be matched in terms of complexity.
- A wireless audio stream is susceptible to radio errors, the codec should be resilient against this.

Coding for Bluetooth

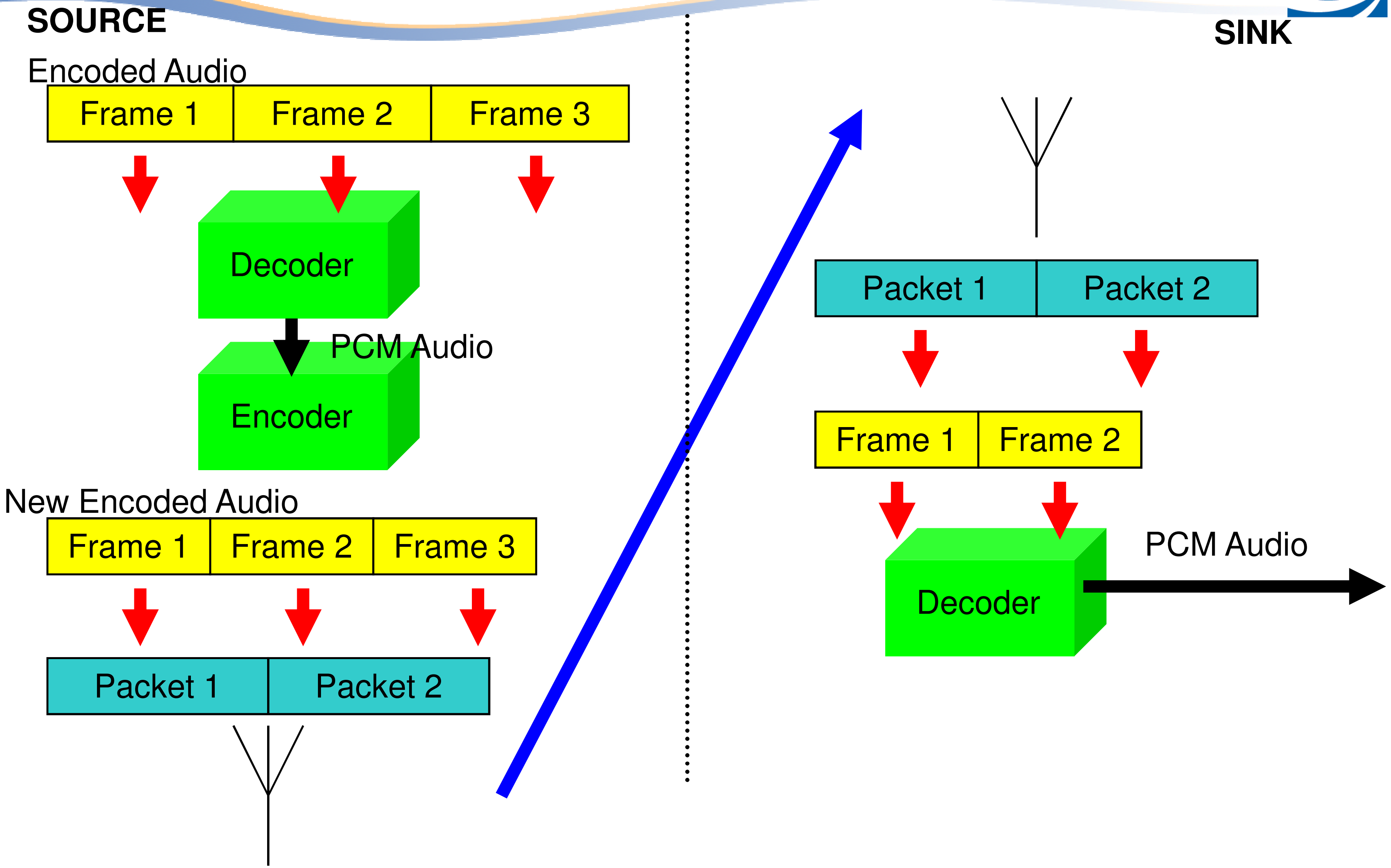
There are two options for source devices:

- Native streaming
  - ✓ No additional processing
  - ✓ Low delay
  - ✗ No local integration of sounds
  - ✗ Receiving device needs to support all the codecs of the source
  - ✗ Interface logic is complex, different codec negotiation per device/use case
- Transcoding
  - ✓ Device performs “as normal” for decoding
  - ✓ Interface logic is simple, wired or Bluetooth
  - ✗ Additional processing and delay

The Bluetooth use case – native transfer



The Bluetooth use case – common transfer

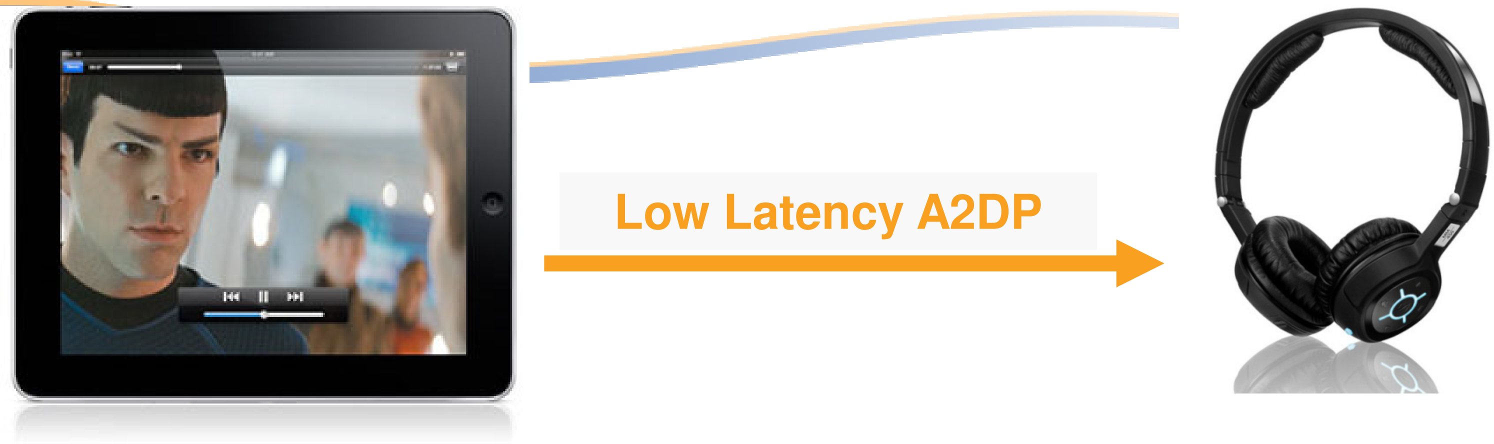


Bluetooth latency

System latency is accumulated at the following points:

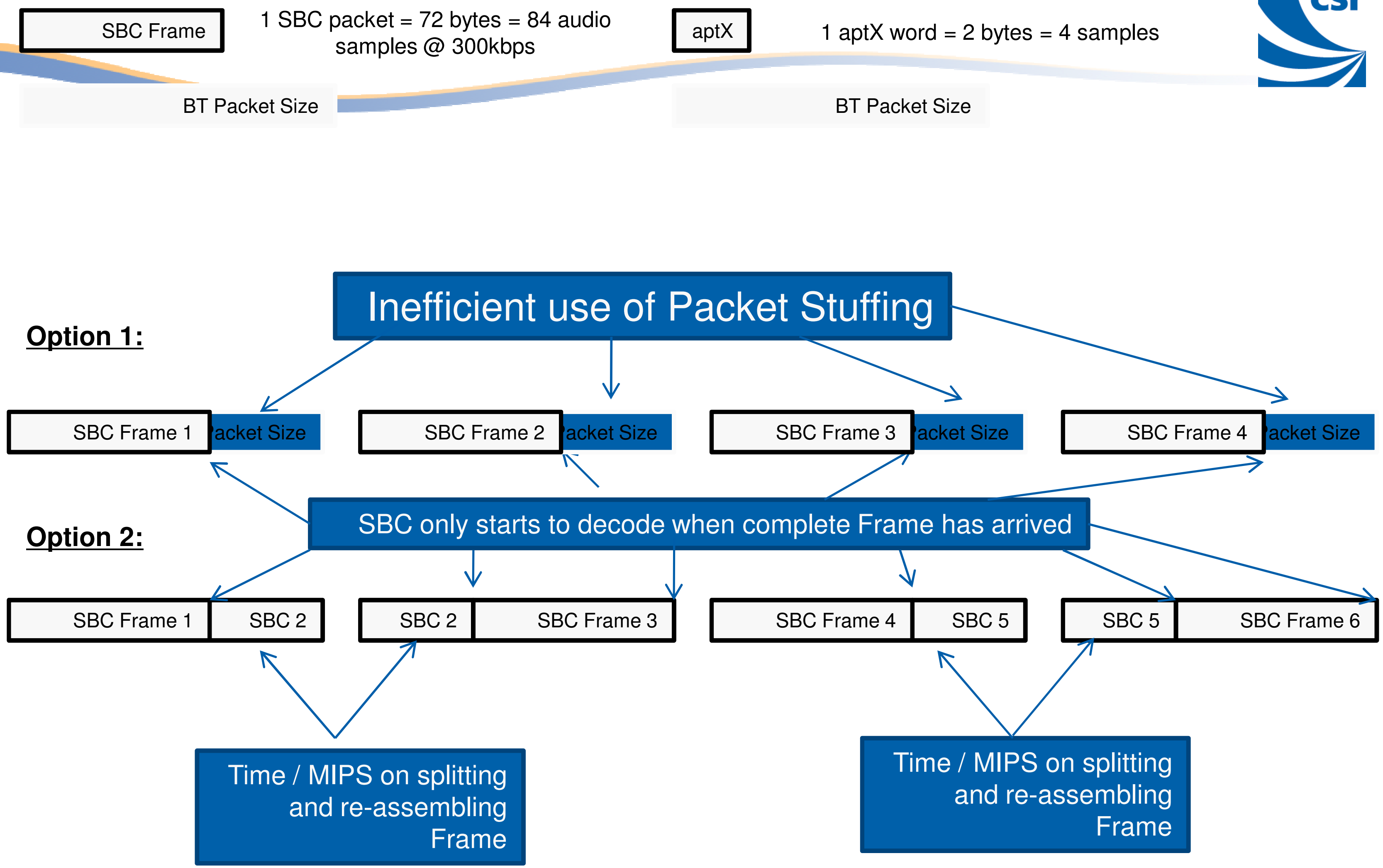
- Transcoding processing at source
- Frame size of codec
- Frame to packet misalignment
- Bluetooth transmission
- Robustness buffering at receiver
  - Frame to packet misalignment
  - Jitter in packet arrival time
  - Retransmissions
  - Rate matching
- Decoding processing

Low Latency (Fast Stream)



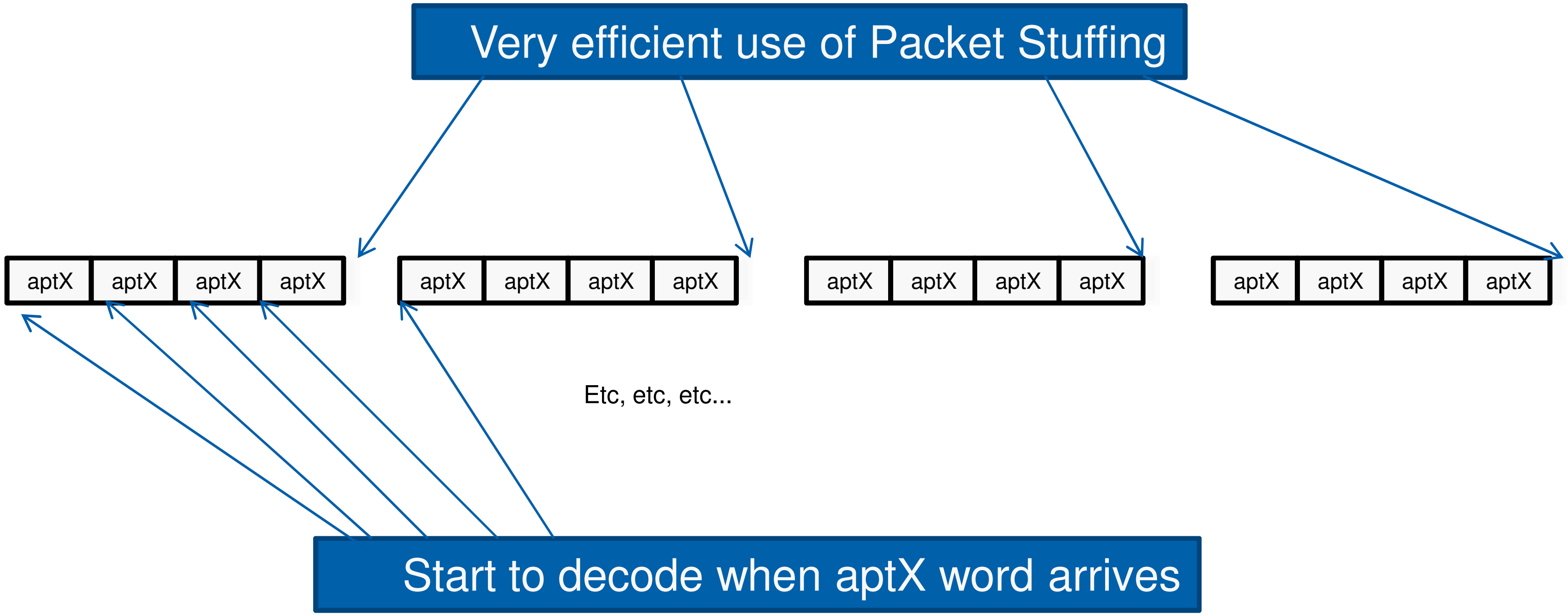
- Lower latency for games and “lip sync” applications
- Video Lip Sync requires a latency below 40ms
- As aptX is a sample based codec, low latency can be achieved through efficient population of packets while retaining transmission robustness
- 32 ms latency from the Audio Adapter
- Requires CSR devices at both ends of the link
- A2DP Vendor specific codec implementation

Frame and Packet Size



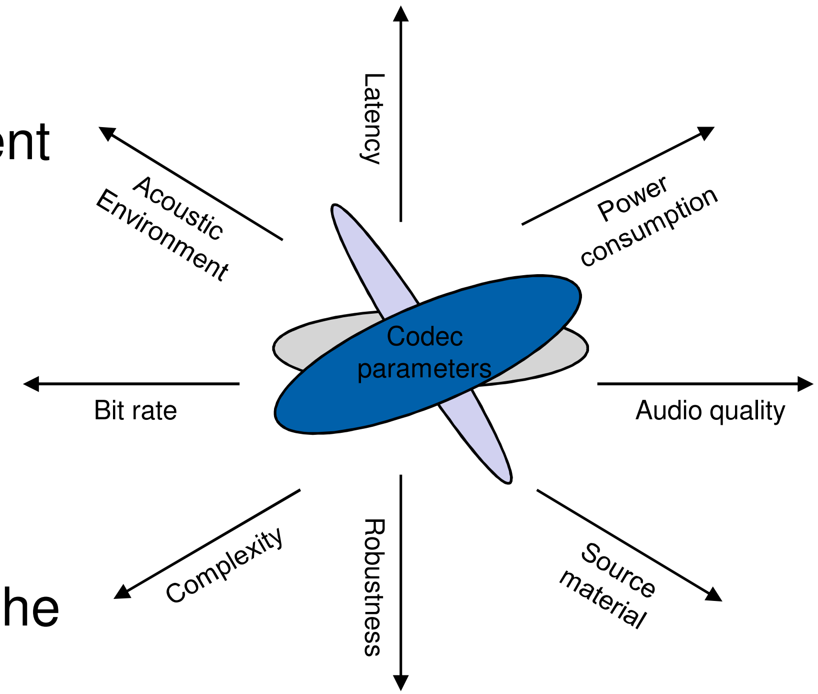
Note: Detail above is for illustrative purposes and not to scale.

Frame and Packet Size Continued....

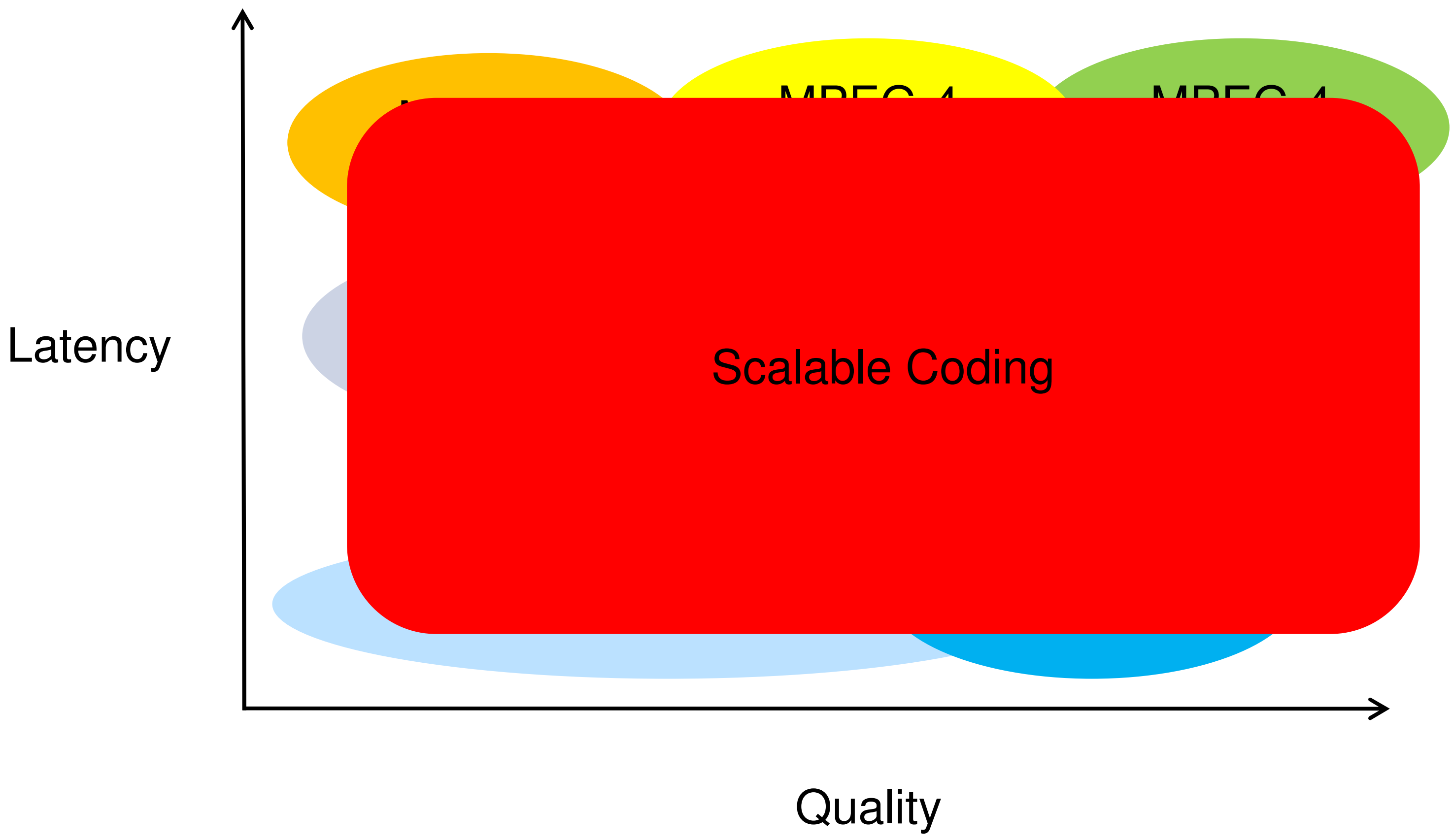


Scalable coding

- Bandwidth over-the-air
  - Reduce/increase the data rate
- Audio quality
  - Expend resources achieving excellent quality when it is applicable.
- Complexity
  - Reduce MIPS when possible and necessary
- Error handling
  - When interference detected, adapt the coding scheme to compensate
- Latency
  - Algorithmic delays vary when required



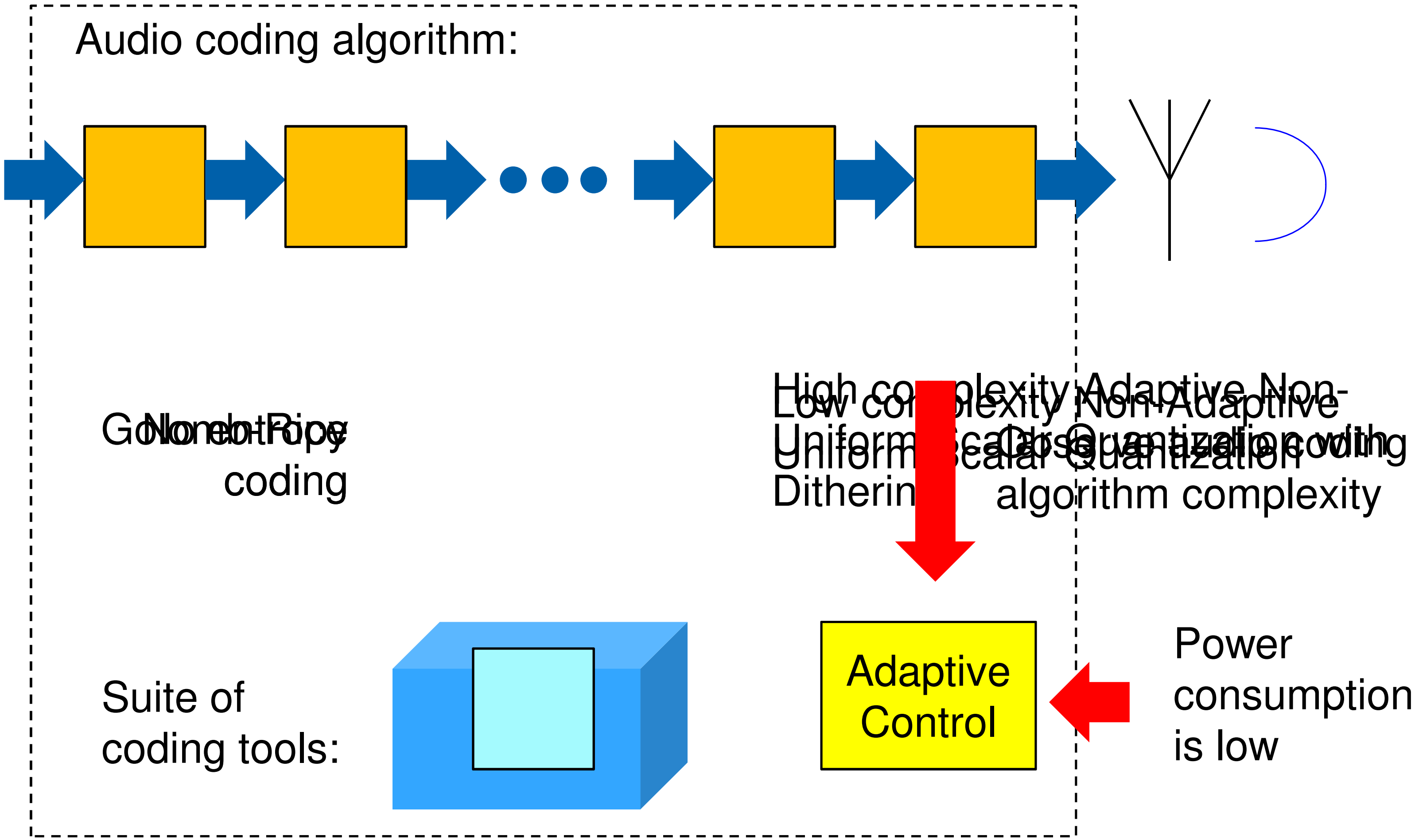
Scalable coding – “sweet spot”



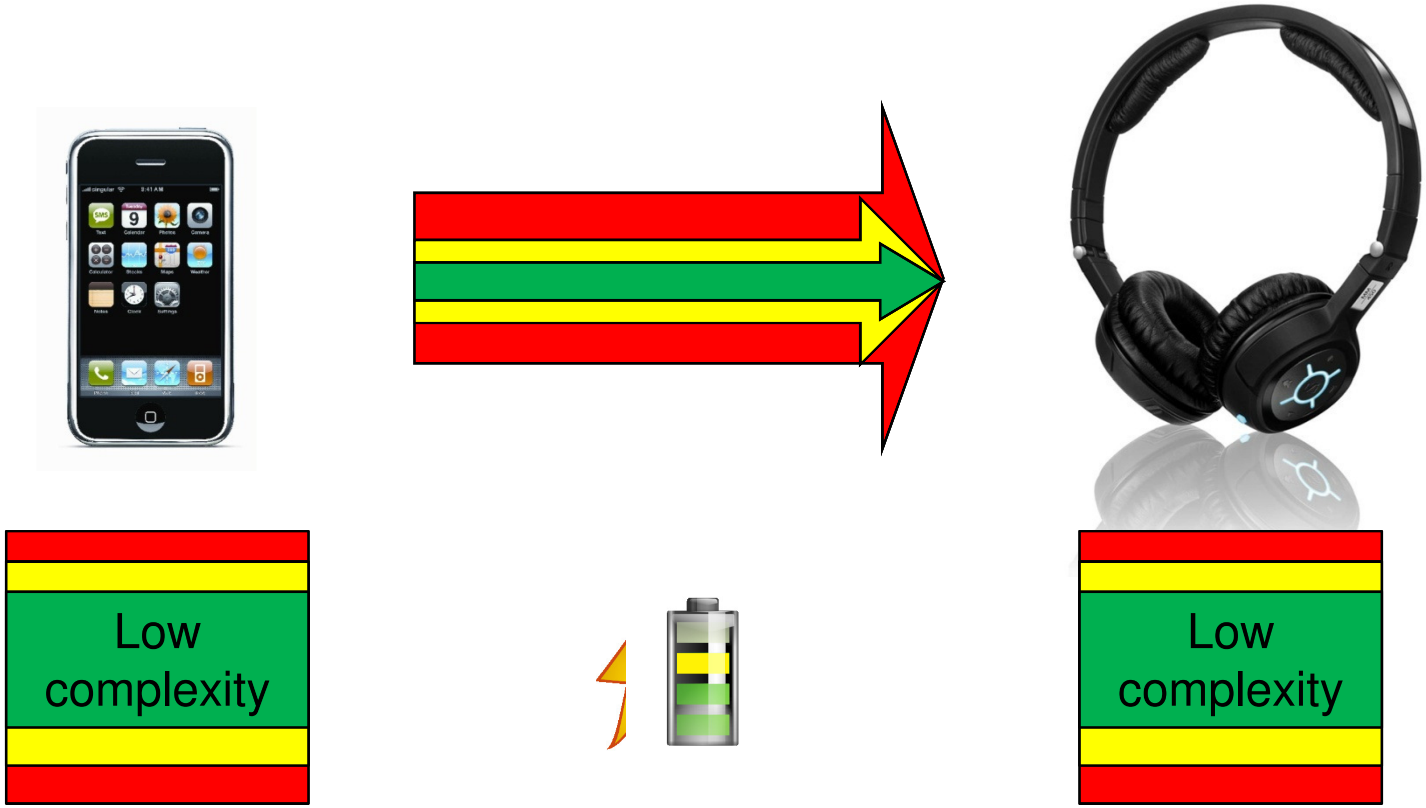
Scalable coding - capabilities

- Scalable latency
- Scalable complexity
- Scalable bit rate
- Scalable error resilience
- Configurable stream structure
- Dynamic and compile-time reconfiguration
- Cognitive adaptation capability
- Backwards compatibility with SBC and aptX

Scalable coding – algorithm adaptation

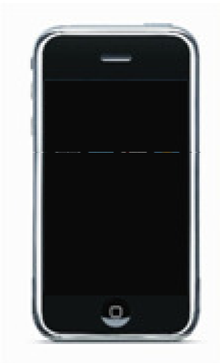


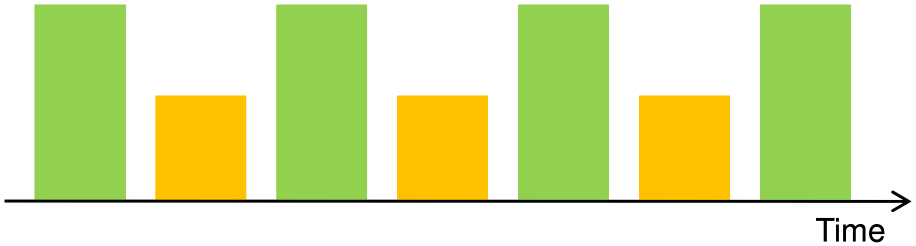
Scalable coding – power consumption



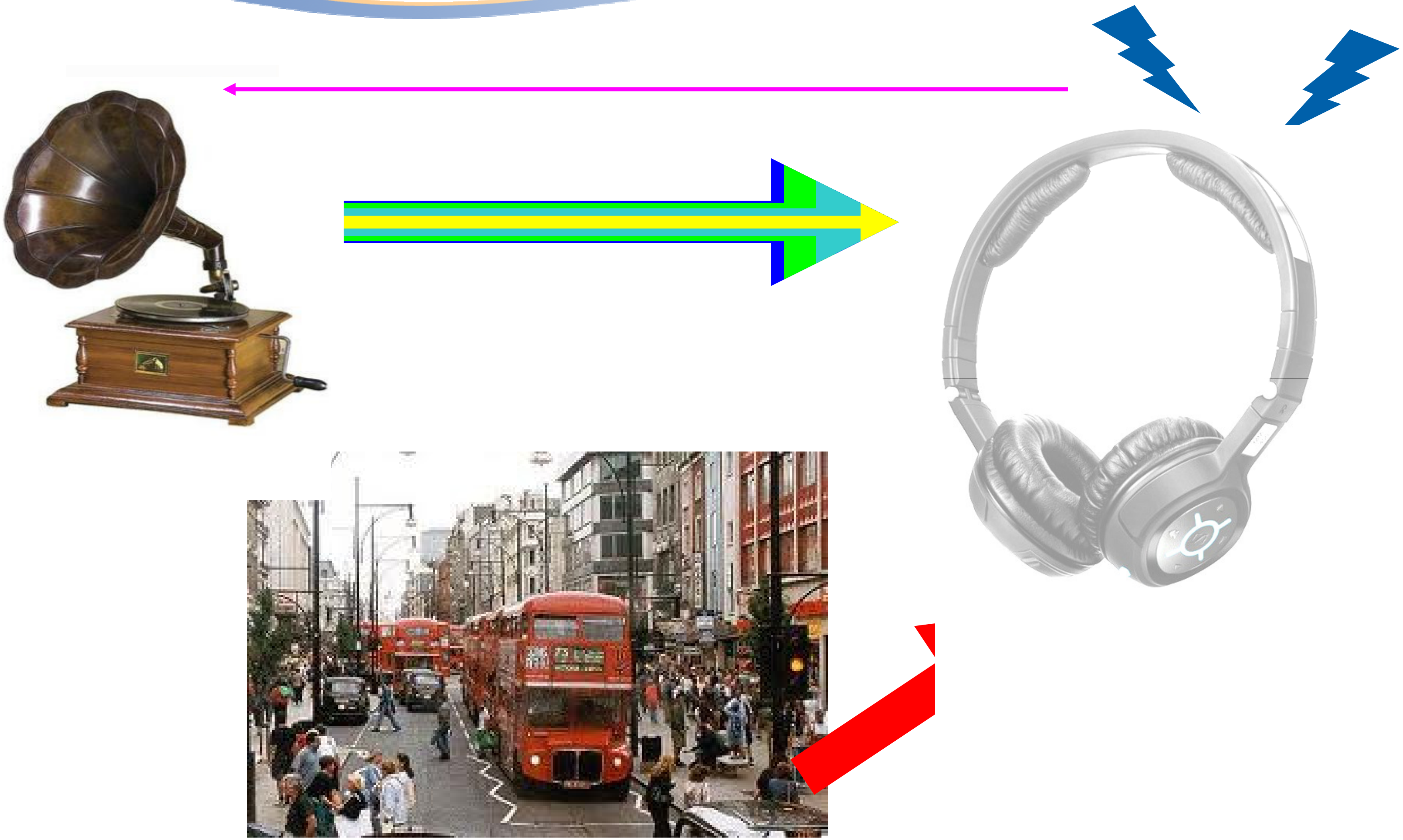
Scalable coding – system constraints

Scalable coding – synchronization





Scalable coding use case – music stream



Scalable coding use case – multi-stream

Scalable coding use case – Dualstream

Scalable coding use case – 2.1

Scalable coding use case – 5.1

Post processing

- Audio stream must be “as good as a wire”
  - ~ No audible artefacts of the transcoding for wireless transfer.
  - ~ Some codecs introduce spectral holes.
- Must handle errors due to interference or lost packets
  - ~ Temporal holes must be masked/filled.
- Must allow post processing of audio
  - ~ Codec compensation
  - ~ Equaliser
  - ~ Dynamic range compression

Audio for wireless microphones

- Professional:
  - Proprietary transmission required to compete with wired microphones
  - Low latency and high quality are paramount
  - Restricted bandwidths require data compression
  - Enhanced level of error tolerance is necessary

Audio for wireless microphones

- Consumer:
  - ~ Bluetooth can offer quality and latency suitable for A/V and interactive multimedia
  - ~ Extend Bluetooth functionality required by many devices for live microphone performance
  - ~ CSR knowledge of entire Bluetooth audio streaming chain provides unique ultra low latency solutions

[illegible]
platforms

Summary

- Wireless audio streaming is not just moving data from device A to device B.
- Must consider the use case, audio content, environment (radio and acoustic), RF ecosystem...
- Use cases overlap, so will RF technologies.
- Coexistence is a significant challenge.

QUESTIONS?