



Emerging Network Forms - 5G, AI and Immersive Media

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Evolution of Wireless Communication

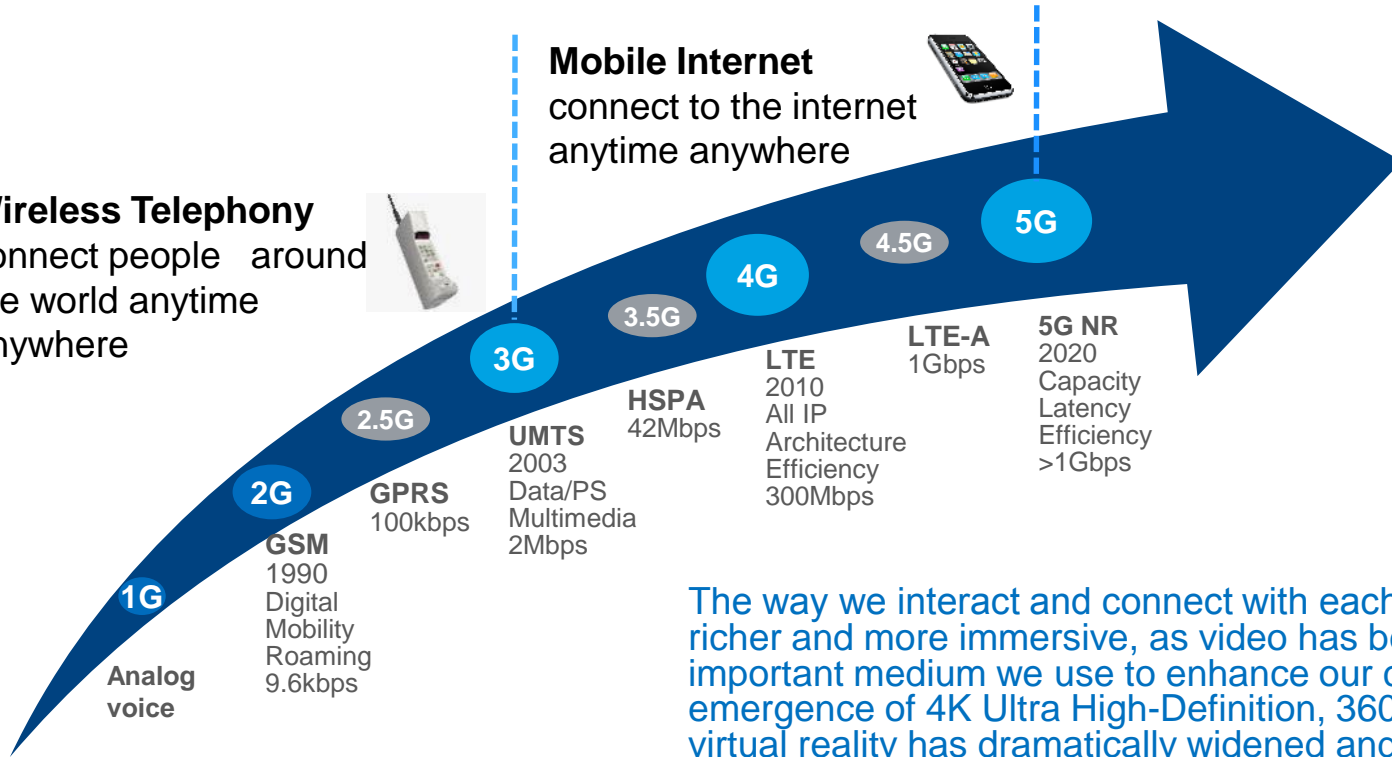
Wireless Telephony
connect people around
the world anytime
anywhere



Mobile Internet
connect to the internet
anytime anywhere



Immersive Internet
virtual world
augments the real
world seamlessly



1G
Analog
voice

2G
GSM
1990
Digital
Mobility
Roaming
9.6kbps

2.5G
GPRS
100kbps

3G
UMTS
2003
Data/PS
Multimedia
2Mbps

3.5G
HSPA
42Mbps

4G
LTE
2010
All IP
Architecture
Efficiency
300Mbps

4.5G
LTE-A
1Gbps

5G
5G NR
2020
Capacity
Latency
Efficiency
>1Gbps

The way we interact and connect with each other has evolved. It's richer and more immersive, as video has become an increasingly important medium we use to enhance our conversations. The emergence of 4K Ultra High-Definition, 360-degree video, and virtual reality has dramatically widened and deepened our vantage points. These trends in how we consume and create content, in how we communicate and interact, reflect what we at Intel call the **immersive internet**. - Navin Shenoy, EVP Intel DCG

Immersive Media Content Creation and Consumption

Immersive Media Capture:

360° Video, 3DoF+, 6 DoF



- **E2E latency down to 20ms**
- **Higher demands on concurrency, continuity and interactivity**



Multiple cameras,
high resolution

Immersive Media Consumption:

360 VR, LF Display



Stereoscopic display,
high pixel quantity and
quality, broad FoV,
minimal latency, natural
UI, precise motion
tracking

Video Type	Bit rate		Basic VR	Ideal VR	Ultimate VR
SD	1.5Mbps	Resolu-tion	Full-view 8K 2D	Full-view 12K 2D	Full-view 24K 2D
HD,1080p30	5Mbps	Bit rate	64Mbps	279Mbps	3.29Gbps
UHD,4kp24/30	15Mbps	Network BW	100Mbps	418Mbps	2.35Gbps (FoV)
UHD,4kp60	25Mbps	Network RTT	30ms	20ms	10ms
UHD,4kp150	60Mbps	Network Pkt Loss	1.5E-5	1.9E-6	5.5E-8
UHD,8kp60	100Mbps				

*Huawei VR Big Data Report 2016

MPEG Video Compression

Immersive experience

- Multiple cameras and at higher view resolutions
 - HD → 1080p full HD → 4K/8K UHD
- Multiple and bigger displays
- 360 degree video, 3DoF+, 6DoF, VR/AR

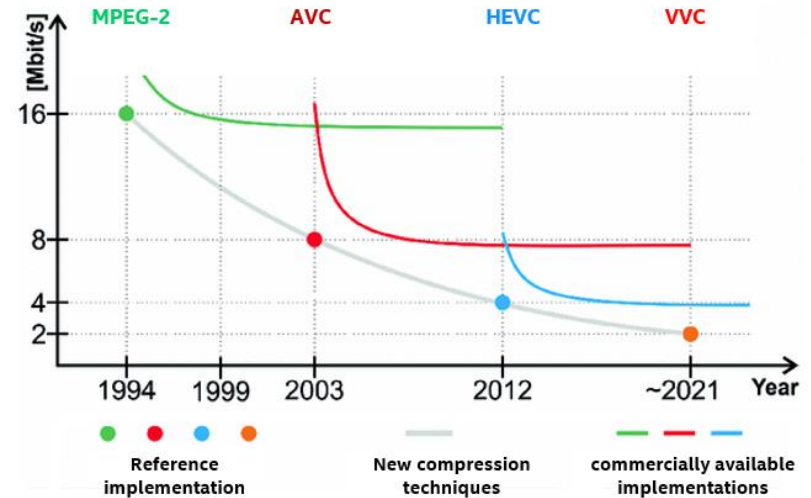
Coding efficiency

- Each new generation of video compression standard doubles the coding efficiency compared to its predecessor

Codec complexity

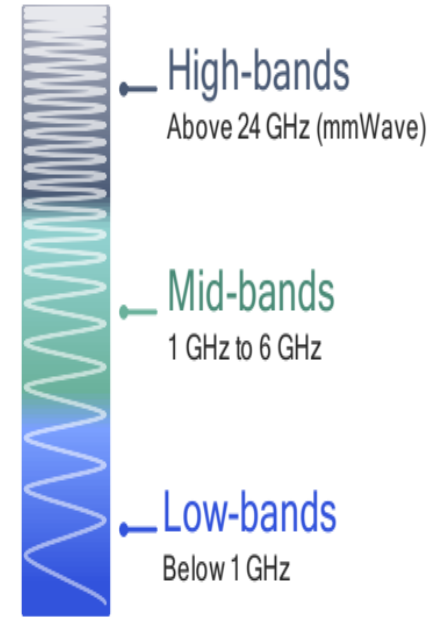
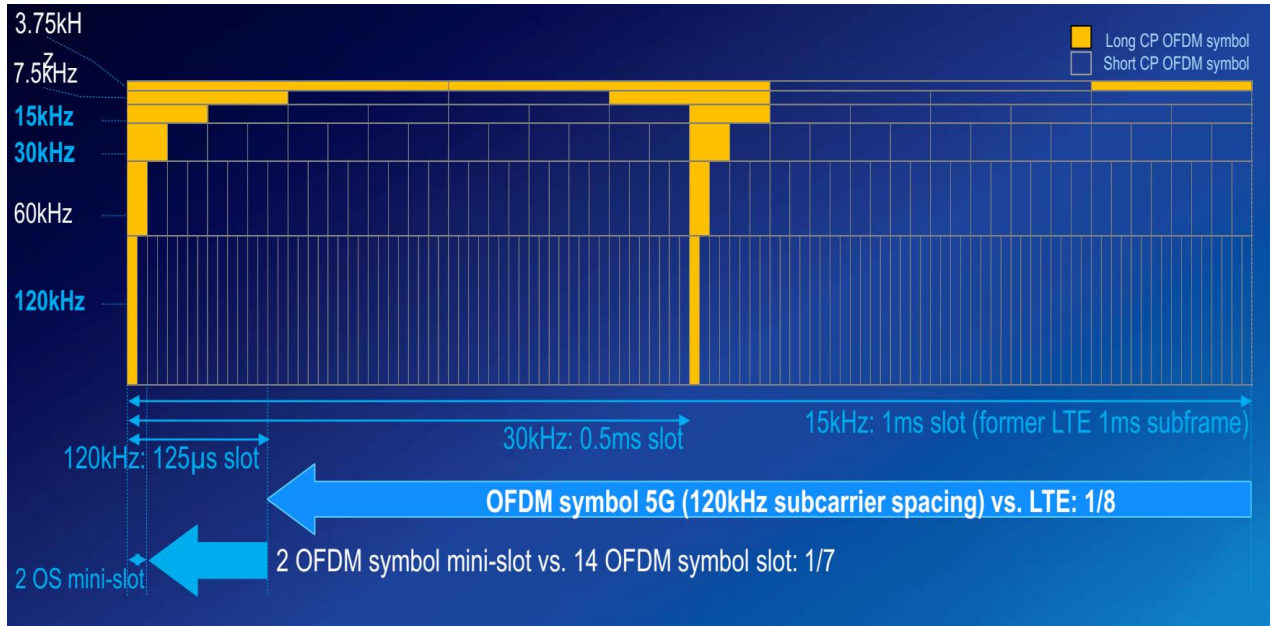
- As a result of increased coding efficiency, video codecs are becoming increasingly complex
- Increased the use of parallel processing architectures.

MPEG Codec Bitrate Trend*



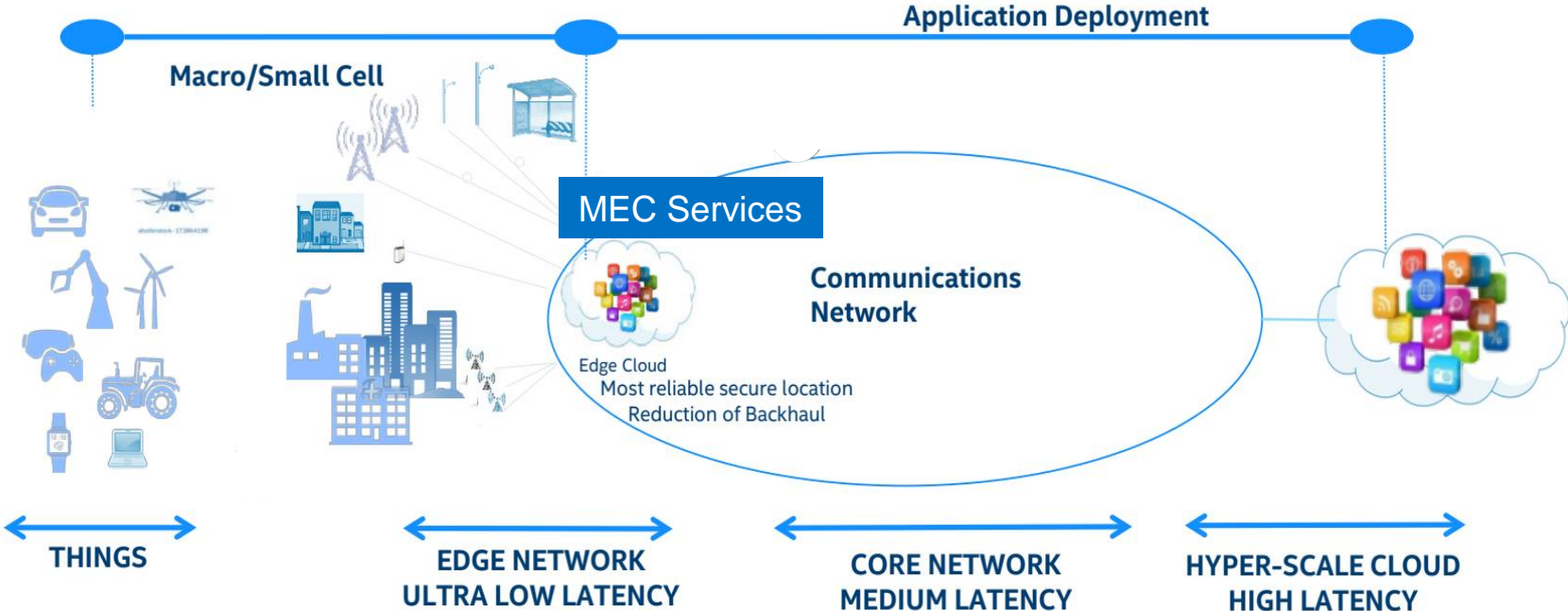
*All video codecs use same video resolution and achieve same target PSNR. Lower bitrate → Higher coding efficiency

5G Low Latency Access



- 5G NR supports scalable numerology to address different spectrum, bandwidth, latency deployments
 - Getting most out of a wide array of spectrum bands
 - Wider bandwidth operation up to 400MHz/Carrier
 - Wider subcarrier spacing and short time slot
- eMBB: U-plane latency <4ms; Peak rate: 20Gbps DL/10Gbps UL
- URLLC: Latency <0.5ms; Reliability: 99.999% @ <1ms & 32Byte

Flexible Network Architecture with SDN/NFV



Compute, Network & Storage Pooled Resources
Standardized Commercial Grade Solutions



Dynamic Flexible Networks
Next-Generation Network Architectures

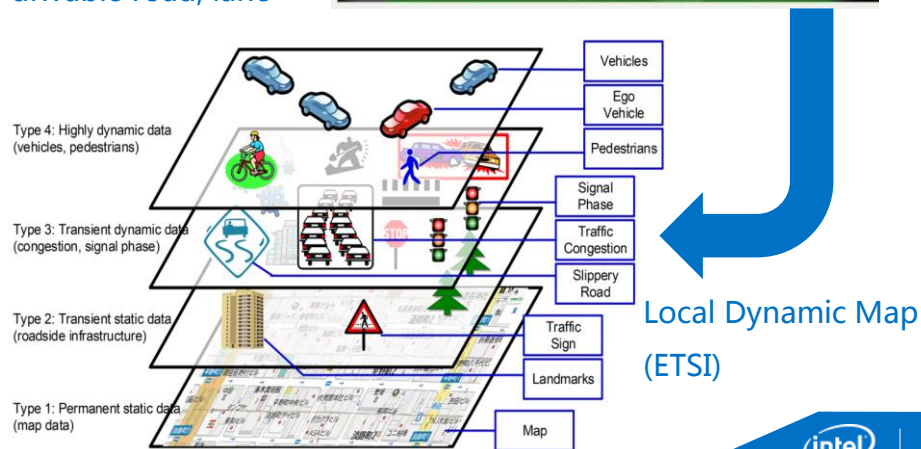


Services Delivery and Agility
Business Process Transformation

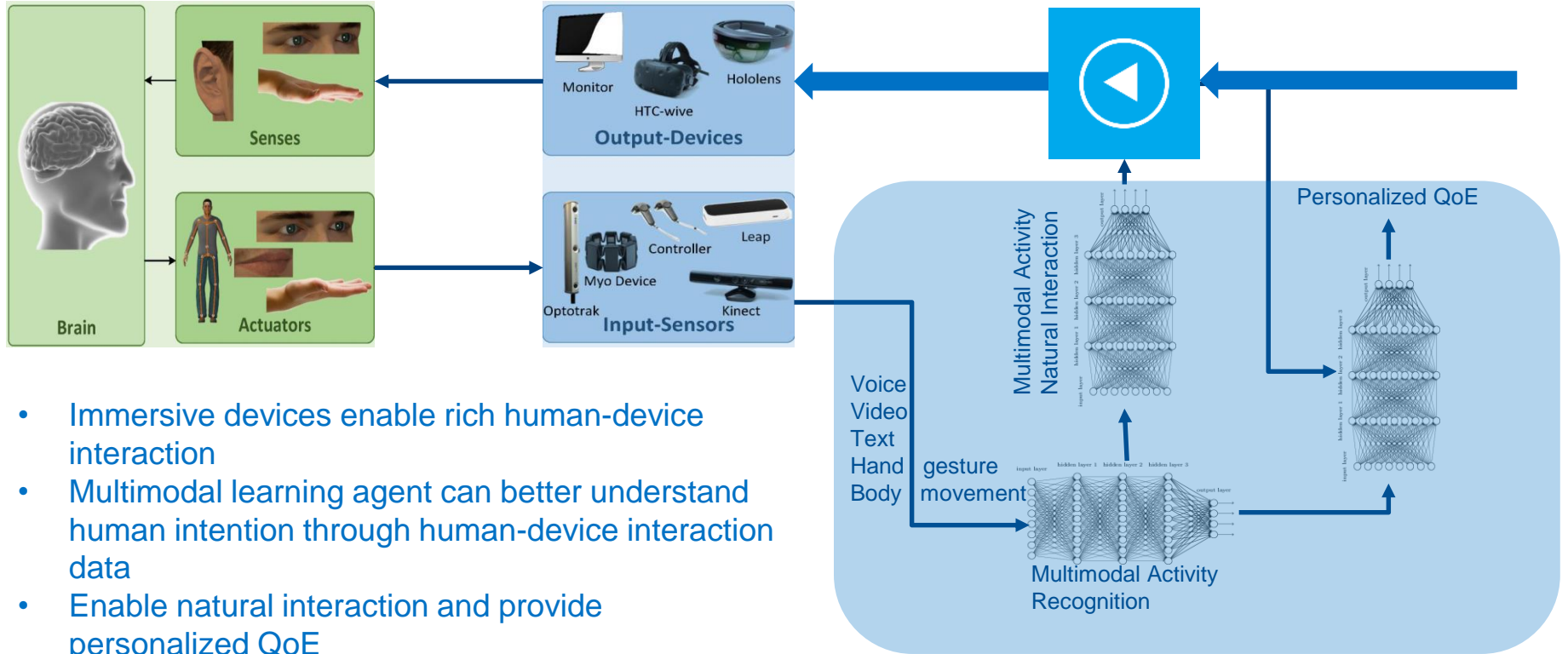
AI Makes Content Transparent



- ❑ Pedestrian, Bicycle;
- ❑ Vehicle, Motorcycle;
- ❑ Traffic sign; Road sign;
- ❑ Traffic light;
- ❑ Road, drivable road, lane

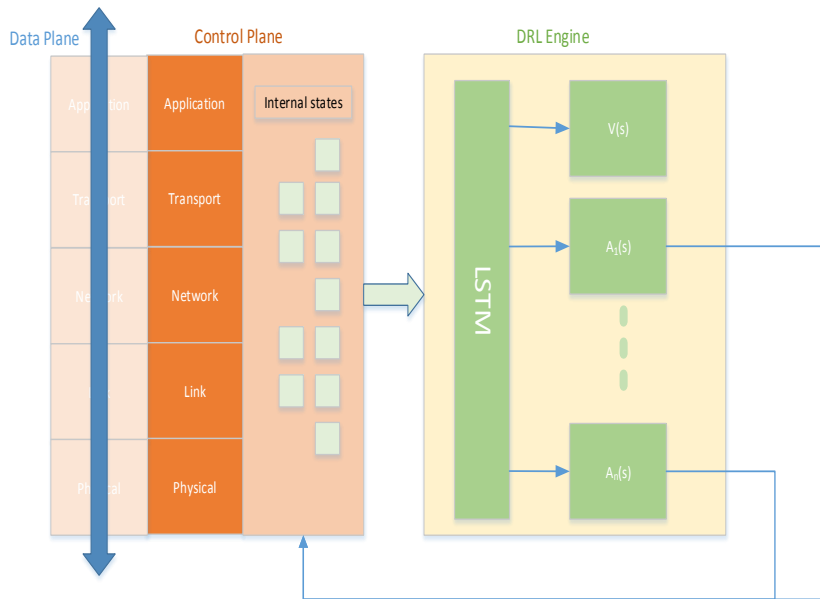


AI Makes User Interaction Natural



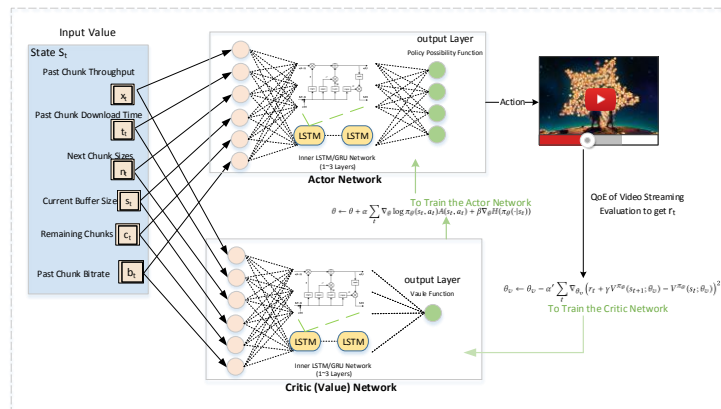
- Immersive devices enable rich human-device interaction
- Multimodal learning agent can better understand human intention through human-device interaction data
- Enable natural interaction and provide personalized QoE

AI Makes Network Layers Transparent

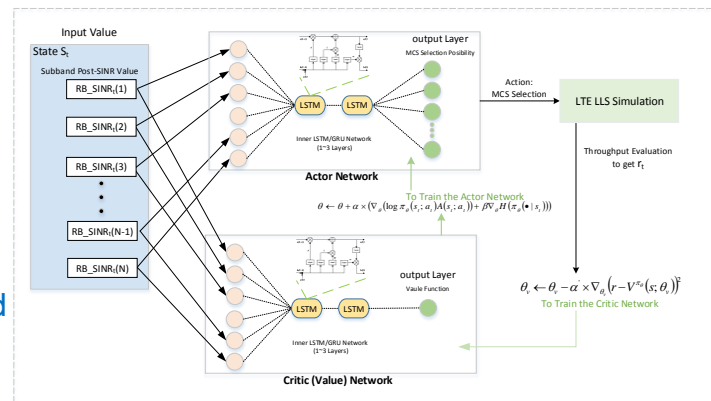


Control plane optimization with DRL

- Cross-layer input at different time scale with LSTM
- Shared value function determined by user/application specific end user performance metric
- End-to-end optimization enforced by shared value function
- Chose optimal policy options at each layer



Application layer video bit rate adaptation



Physical layer link adaptation

The Master Algorithm

To enable virtual world seamlessly augmenting the real world

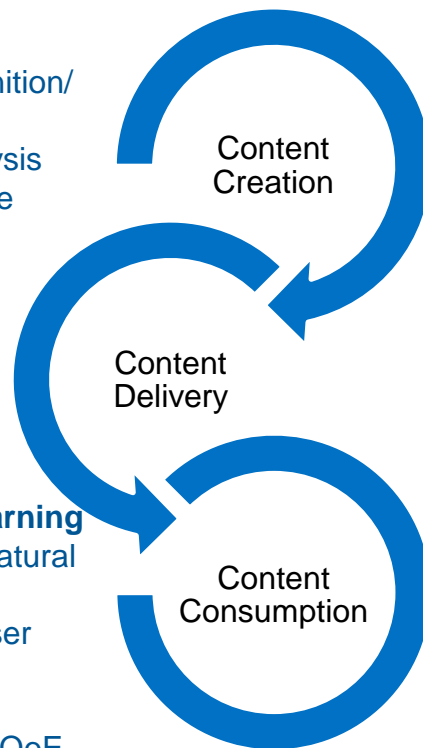
- **At source:** know the content
- **At destination:** know then end-user perception
- **In delivery:** optimize information delivery to best match content with user perception

Deep Learning

- Object recognition/classification
- Content analysis
- Content aware processing

Multimodal Learning

- Multimodal natural interaction
- Multimodal user perception assessment
- Personalized QoE

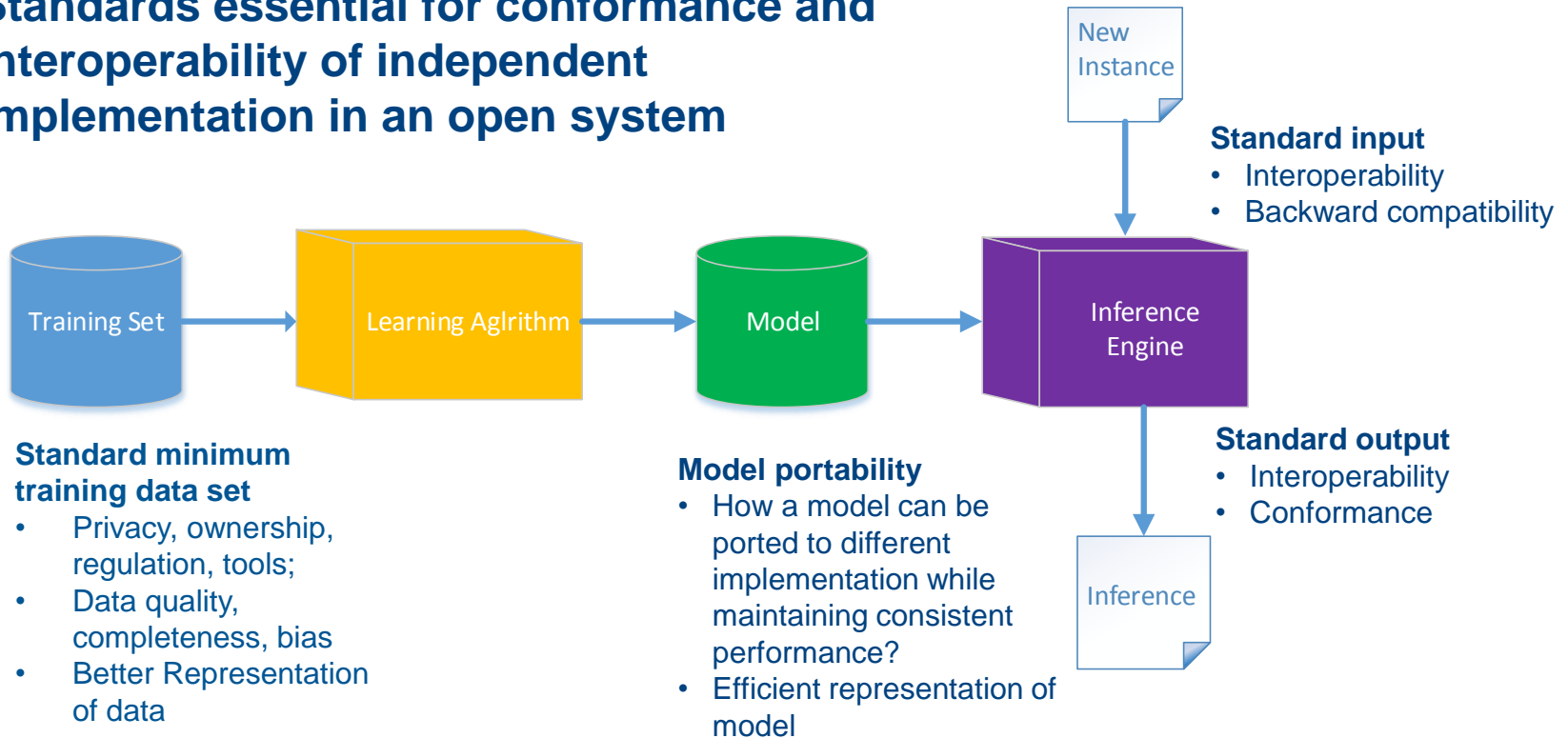


Deep Reinforcement Learning

- E2E QoE assurance
- Cross-layer optimization
- Cross-RAT optimization
- Mobility management
- Energy efficiency

Standard Consideration for AI

Standards essential for conformance and interoperability of independent implementation in an open system



backup