Elastic ICN Packet Format
“draft-ravi-elastic-icn-format-00”

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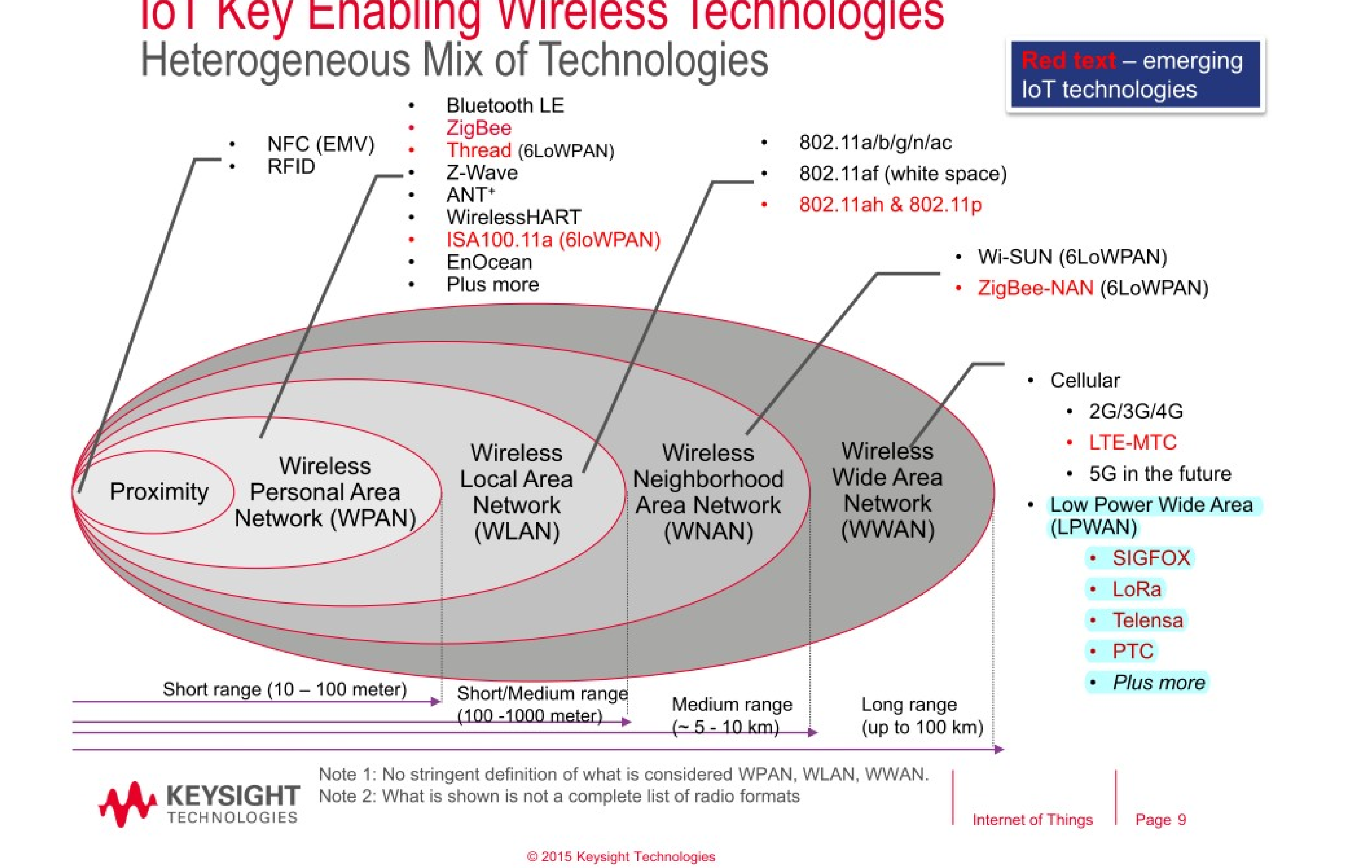
Elastic Packet Format Motivation

- **Universality** : One protocol for IoT with small MTU capability and infrastructure with large MTU capability considering future Optical and wireless networks. Follows the requirement from [1]
- **Transport Overhead**: Considering Mobile Internet and IoT scenarios, minimizing the transport overhead is desirable.
  - We propose a 3B fixed transport overhead compare to 8B of CCNx1.0. Savings results in 6% less packet overhead for 15.4, 23% for BTLE, and 42% for SIGFOX [ref].
- **IoT Opportunity**: Considering the issue of inter-operability in IoT today, *having one protocol specification applicable to both constrained as well as to the infrastructure avoiding protocol gateways could be a distinguishing factor for ICN.*

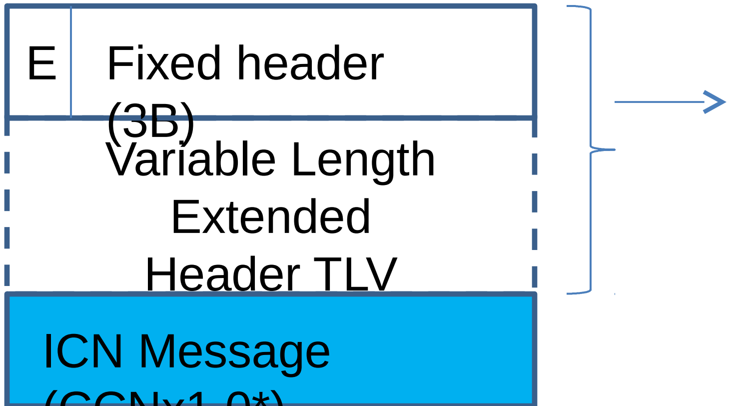
[1] Alex Afanasyev et al , “https://tools.ietf.org/id/draft-icn-packet-format-requirements-00.txt.", 2015.



- **Majority of IoT devices will be accessed over wireless interfaces which is sensitive to protocol transport headers because of issues like Battery Life, Spectrum Usage etc.**

Elastic ICN Packet Proposal

- Aims to reduce the fixed header size, includes only important fields to enable ICN transport processing.
- Other fields such as hop-by-hop fields are part of a Extended Header TLV. The Extended Header can also include fixed part to include Reserved Byte, QoS Marking etc.
- The first E bit in the Fixed header identifies the presence of the Extended header TLV.
- The ICN messages can follow CCNx1.0, with enhancements to allow efficient encoding for large MTU payloads.
  - For very smaller MTU, a 1+0 TL encoding can be included in the protocol spec.



The proposal focuses on the transport Header.

Interest Packet Encoding

- 3B fixed header, with optional hop-by-hop fields such as Interest life time in an Extended Header TLV.
- The Interest packet length is expected to be <255B, hence 1B length should be sufficient.
- Optional Length TLV is used if the Interest Packet is >255B.

3B Fixed Header

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|E| Ver | Msg   |   Hop Limit   |   Length      |  Extended
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                            Header TLV                          \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                       Interest Message                        \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                              ...                              \
```

Extended header TLV

3 Byte Fixed head with Extended header TLV

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
| MessageType =T_EXTENDED_HEADER|       Extended Header  Len    |
+---------------+---------------+---------------+---------------+
\                <Optional  Length TLV>                         \
+---------------+---------------+---------------+---------------+
\                 <Optional  Interest Life Time TLV>            \
+---------------+---------------+---------------+---------------+
\                              ...                             \
```

Variable Length Extended header TLV

Interest Packet Encoding

General and Interest Specific Interpretation:

- **E bit**: This bit identifies the presence of an Extended Header TLV in the Interest message.
- **Version**: These 3 bits identifies the ICN protocol version. Significant version changes happen over long timescales.
- **Message type**: These 4 bits identifies the message type, such as Interest, Content Object etc, allowing 15 message primitives.
- **Hop Limit**: This field is only relevant to Interest messages. This is set by the first CCN forwarder and decremented at every hop. When the value is zero, the Interest is dropped.
- **Length** : **This Byte is set to the size of the total ICN protocol message which includes the fixed and Extended Header if present**.
  - If the total packet size is greater than 255 Byte then this field is set to 0x00; the total message length is then encoded in the Extended Header using the Optional Length TLV.
- **Extended Header TLV**: This TLV container is identified with a new type code (T_EXTENDED_HEADER) and encapsulates transport and Interest related metadata TLV such as Optional Length or Interest lifetime.
  - we do not exclude the possibility of having a fixed portion in the Extended Header TLV container, such as for a reserved field, QoS descriptors along with TLV encoded fields.
- **ICN Interest Message**: This is the ICN Interest message defined in CCNx1.0 proposal.

Content Object Encoding

- **3B fixed header, with optional hop-by-hop fields such as cache lifetime in the Extended Header TLV.**
- **The 2B length allows 64KB size of Content Object message.**
- **Optional Length TLV is used if the Content Object is >64KB.**
- **Optional Length in this case also allows to define new Length types, e.g. 4B length type to enable 4GB CO message.**

3B Fixed Header

Extended header TLV

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|E| Ver | Msg   |     Length                    | Extended
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
                        Header TLV                             \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                   ICN Content Object Message                 \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                            ...                               \
```

Content Object Transport Header

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---------------+---------------+---------------+---------------+
| MessageType =T_EXTENDED_HEADER|     Extended Header Length    |
+---------------+---------------+---------------+---------------+
\               <Optional  Length TLV>                          \
+---------------+---------------+---------------+---------------+
\                <Optional  Cache Life Time TLV>                \
+---------------+---------------+---------------+---------------+
\                            ...                                \
```

Figure 4: Extended Header TLV Container for Content Object.

Content Object Encoding

- Fields retain the same definition as in the previous slide, the new interpretations are provided here.
- **Length** : The Content Object Length is defined in 2B and represents the total packet length i.e. including the Content Object, fixed and Extended header.
  - If the packet length is larger than 64KB, then this field is set to 0x0000 indicating that the packet length is encoded in the Extended Header using the Optional Length TLV. This flexible length definition allows large Content Object payloads, which is further discussed later.
- **Extended Header TLV**: The container encapsulates network and Content Object related metadata such as Optional Length and Cache lifetime.
  - The Extended Header Length is the sum of all hop-by-hop TLV included in the Extended TLV container.
- **Content Object Message**: This is same as the Content Object in CCNx1.0 proposal. However, the proposed encoding allows messages larger than 64KB. This is because of TLV encoding of length in the Extended Header that allows multiple length type definitions.
  - For e.g., while the default is 2 Byte length in the fixed header, a new type such as LEN_TYPE_4GB can be defined in the Optional Length TLV with 4B length value in the Extended Header to encode Content Object payloads up to 4GB size.

Encoding Examples: Small and Large Interest Payloads

Example-1: Interest message with length less than 255 Bytes is shown in Fig. 5.

```
  0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0| Ver | Msg=I |    Hop Limit   |    Length <255 |   Interest
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                       Message                                 \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                    ...                                       \
```

Figure 5: Encoding for Interest payload less than 255 Bytes.

Example-2: Interest payload with length up to 64KB is shown in Fig. 6. In this case, the Optional Length TLV in the Extended Header encodes the size of the total Interest packet. The Optional Length type DEFAULT indicates 2 Byte length field.

```
  0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1| Ver | Msg=I |    Hop Limit  |    0x0000      |Type= T_EXTENDED
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
_HEADER         |  Extended Header Len =  6     |Optional Length
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 Type =  DEFAULT|          Length               | Value
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |  Interest Message                            \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                    ...                                    \
```

Figure 6: Encoding for Interest payload up to 64KB.

Encoding Examples: Small and Large Content Object Message

Example-3: Content Object with length less than 64KB is shown in Fig. 7.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|0| Ver | Msg=C |    Length                     | Content Object
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                | Length                        | Content
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                          Object Payload                         \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                              ...                                \
```

Figure 7: Encoding for Content Object payload up to 64KB.

Example-4: A Content Object encoding capable of transporting up to 4GB Content Object is shown in Fig. 8. In this case a new type of Optional Length TLV of type LEN_TYPE_4GB of size 4 Byte is defined in the Extended Header.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1| Ver | Msg   |    Length=0x0000              |Type= T_EXTENDED
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 _HEADER        |   Length = 8                  | LEN_TYPE_4GB
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                |   Length = 4                  |  Length Value
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
                                                | CCN Msg Type =
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
Content Object  | LEN_TYPE_4GB                  |   Content     \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                       Object Payload                          \
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
\                             ...                               \
```

Figure 8: Encoding for Content Object payload up to 4GB.

Energy saving numerical results from reducing 5 bytes.

	Zigbee1	BLE1	SIGFOX2	802.15.43
Original energy consumption	35.706mW	147uW	4800mW	1.216mW
Energy consumption after reducing 5 Bytes*	31.128mW	119.7uW	3300mW	1.176mW
power reduction percentage	12.80%	18.50%	31.25%	3.20%

- Zigbee : Sending *24 Bytes payload with 15 bytes header* costs 35.706mW.

- BLE : 3 channels, each channel broadcasts a packet with *20 bytes payload and 7 bytes header* every 500ms. It consumes 49 μA at 3 V each second. That's 0.147μW.

- SIGFOX: *12 Bytes payload with 4 bytes header.* Power efficiency is 50 μW per bit.

- IEEE 802.15.4: *127 bytes payload with 25 bytes header*. 250kb/s data rate under 2.5GHz frequency, 1mW/MHz for over 1000 Hz .

*According to reference [4], we assume the energy consumption is proportional to the packet length.

1. http://www.digikey.com/en/articles/techzone/2011/aug/comparing-low-power-wireless-technologies
2. http://www.unlockpwd.com/the-sigfox-network-is-bidirectional-and-here-is-the-proof-of-his-way-back/
3. http://ecee.colorado.edu/~liue/teaching/comm_standards/2011F_802.15.4/index.htm
4. Feeney, L.M.; Nilsson, M., "Investigating the energy consumption of a wireless network interface in an ad hoc networking environment," *INFOCOM 2001. IEEE* , vol.3, no., pp.1548,1557 vol.3, 2001

Conclusions

- Elastic ICN Packet format is motivated considering single protocol spec both for IoT and infrastructure world.
- Reduces fixed packet overhead by 5B compared to CCNx1.0, considerable saving for low power radio.
- Optional ICN payload length definition in the Extended Header TLV allows accommodation of large ICN payloads, e.g. for transport over high bandwidth optical or wireless networks.