Writing an OSTINATO PROTOCOL BUILDER

How to add more protocols to the Ostinato traffic generator

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What is Ostinato?

Packet Crafter ‘n Traffic Generator

Software only, Open Source

Cross Platform – Windows, MacOS, Linux

Ostinato – a brief history

- Started 2007
- Public launch Apr 2010 – v0.1
- The BIG ONE-O Sep 2019 – v1.0
- Lead developer-maintainer
- Side project
- Project sustained via paid binaries

Ostinato – features

- Multiple streams (stream = sequence of packets)
- Per stream: rates, bursts, no. of packets, stats
- Real time Port Statistics
- Device Emulation (ARP, Ping)
- Common protocols (VLAN, IP, TCP, UDP, IGMP etc.)
  - Stateless only; no stateful support
- Set/Edit value for any field of any protocol
- Vary packet fields
- PCAP import, edit and replay
- … and many more!

Wireshark in Reverse

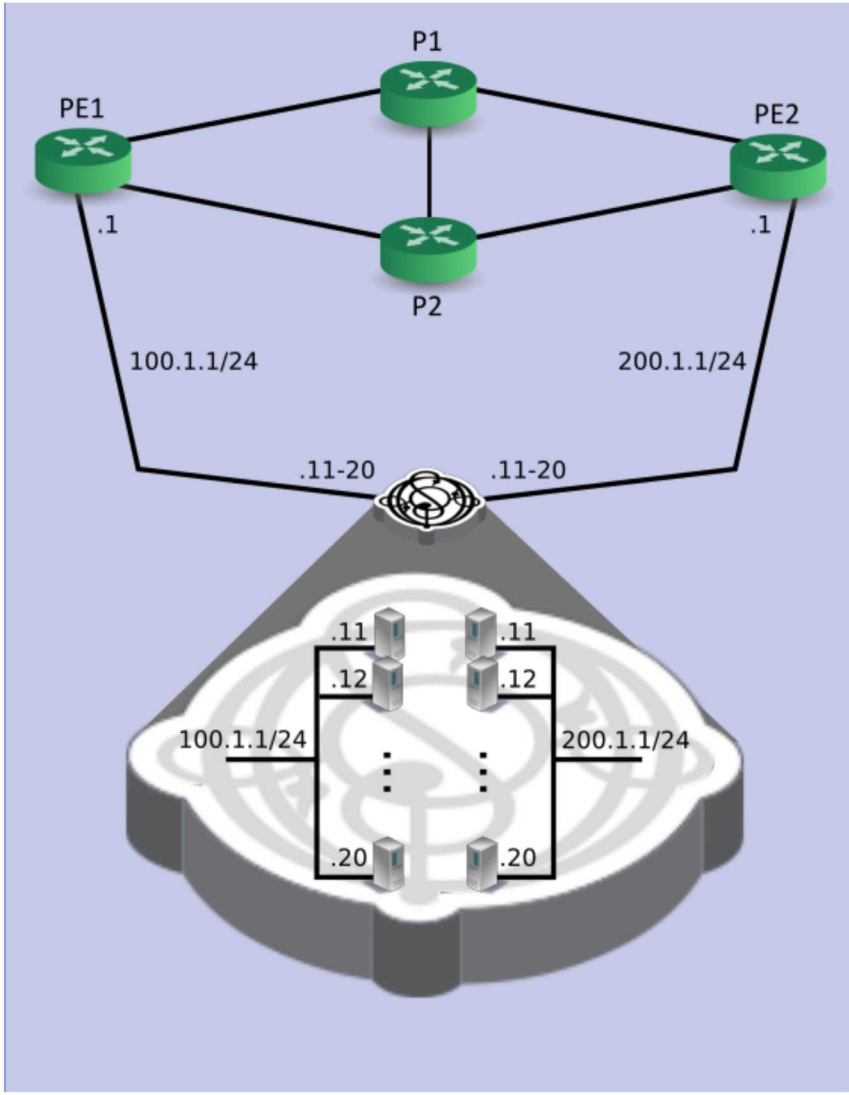
Demos and more

Learn more and
watch Ostinato demo videos

https://ostinato.org/docs/sharkfest2020

Ostinato demos

- Basics
  - Packets from scratch
  - Pcap import/edit/replay
- Scenarios
  - Routing test
  - IMIX test
  - IGMP/multicast test



Currently supported protocols

L2	L3	L4	L5	Misc
Mac	ARP	ICMP (v4/v6)	Text	HexDump
Eth2	IPv4	IGMP	Pattern Payload	UserScript
802.3	IPv6	MLD		
LLC	IPoverIP (v4/v6)	TCP		
SNAP	STP	UDP		
VLAN				

As of Jan 2021

New protocols can be added using Ostinato's
Protocol Builder Framework

Code - Language and dependencies

- Language
  - C++
  - Protocol buffers
- Dependencies
  - Qt 5.9+
  - Protobuf 2.6+
  - libpcap/npcap
  - libnl3, libnl-route3 (Linux only)

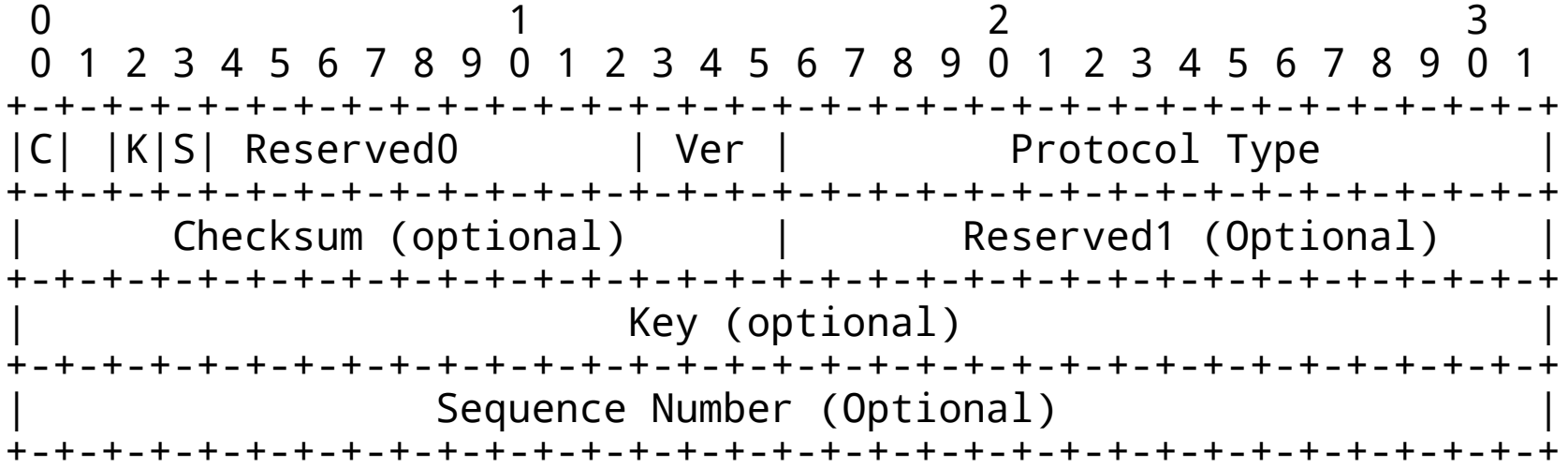
What is a Protocol Builder?

- Wireshark
  - Captures packets and dissects them
  - **“Protocol Dissectors”**
- Ostinato
  - Builds packets and puts them on the wire
  - **“Protocol Builders”**

Parts of a Protocol Builder

- Core
  - `sample.proto, {sample.pb.h, sample.pb.cc}, sample.h, sample.cpp`
- GUI widget
  - `sample.ui, {ui_sample.h}, sampleconfig.h, sampleconfig.cpp`
- PCAP import
  - `samplepdml.h, samplepdml.cpp`
- These are actual files from Ostinato code
  - template for new protocol builders
  - includes boilerplate code
  - and TODO instructions for protocol specific code

GRE – Frame Format



(RFC 2890)

GRE Protocol Builder files

- Copy and rename template files
  - `sample*.*` to `gre*.*`
  - Find & Replace `SAMPLE/Sample/sample` with `GRE/Gre/gre` in the gre*.* files
- New files
  - Core: `gre.proto, {gre.pb.h, gre.pb.cc}, gre.h, gre.cpp`
  - GUI widget: `gre.ui, {ui_gre.h}, greconfig.h, greconfig.cpp`
  - PCAP import: `grepdml.h, grepdml.cpp`
- Modified Files
  - Definition: `protocol.proto`
  - Registration: `protocolmanager.cpp, protocolwidgetfactory.cpp, pdmlreader.cpp`
  - Build/Project: `ostproto.pro, ostprotogui.pro`

GRE Core

`gre.proto, gre.h, gre.cpp`

GRE Core (gre.proto)

```
import "protocol.proto";

package OstProto;

// GRE Protocol
message Gre {
    optional uint32     flags = 1 [default = 0xa];
    optional uint32     rsvd0 = 2;
    optional uint32     version = 3;
    optional uint32     protocol_type = 4;
    optional uint32     checksum = 5;
    optional uint32     rsvd1 = 6;
    optional uint32     key = 7 [default = 0x2020bad7];
    optional uint32     sequence_num = 8;
}

extend Protocol {
    optional Gre gre = 405;
}
```

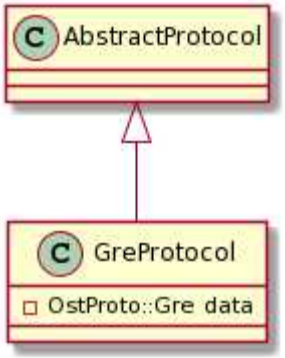
GRE Core (protocol.proto)

```
--- a/common/protocol.proto
+++ b/common/protocol.proto
@@ -156,6 +156,7 @@ message Protocol {
          kIcmpFieldNumber = 402;
          kIgmpFieldNumber = 403;
          kMldFieldNumber = 404;
+         kGreFieldNumber = 405;

          kTextProtocolFieldNumber = 500;
      }
```

GRE Core (gre.proto ==> gre.pb.[h,cc])

```
// protoc generated class

namespace OstProto {
// ...
class Gre : public ::google::protobuf::Message {
  // ...
  // optional uint32 flags = 1 [default = 10];
  inline bool has_flags() const;
  inline void clear_flags();
  static const int kFlagsFieldNumber = 1;
  inline ::google::protobuf::uint32 flags() const;
  inline void set_flags(::google::protobuf::uint32 value);
  // ...
}
}
```

GRE Core class (diagram)



GRE Core (gre.h)

```
#define GRE_FLAG_CKSUM 0x8
#define GRE_FLAG_KEY   0x2
#define GRE_FLAG_SEQ   0x1

class GreProtocol : public AbstractProtocol
{
public:
    enum grefield
    {
        // Frame Fields
        gre_flags = 0,
        gre_rsvd0,
        gre_version,
        gre_protocol,
        gre_checksum,
        gre_rsvd1,
        gre_key,
        gre_sequence,

        gre_fieldCount
    };

    // ...

private:
    OstProto::Gre data;
}
```

GRE Core (gre.cpp) – Boilerplate functions

```
// Same as template - no need to modify

AbstractProtocol* GreProtocol::createInstance(StreamBase *stream,
    AbstractProtocol *parent) {
    return new GreProtocol(stream, parent);
}

quint32 GreProtocol::protocolNumber() const {
    return OstProto::Protocol::kGreFieldNumber;
}

void GreProtocol::protoDataCopyInto(OstProto::Protocol &protocol) const {
    protocol.MutableExtension(OstProto::gre)->CopyFrom(data);
    protocol.mutable_protocol_id()->set_id(protocolNumber());
}

void GreProtocol::protoDataCopyFrom(const OstProto::Protocol &protocol) {
    if (protocol.protocol_id().id() == protocolNumber() &&
            protocol.HasExtension(OstProto::gre))
        data.MergeFrom(protocol.GetExtension(OstProto::gre));
}
```

GRE Core (gre.cpp) – Names and IDs

```
QString GreProtocol::name() const {
    return QString("General Routing Encapsulation Protocol");
}

QString GreProtocol::shortName() const {
    return QString("GRE");
}

AbstractProtocol::ProtocolIdType GreProtocol::protocolIdType() const {
    return ProtocolIdEth; // Types are ProtocolId[None|Llc|Eth|Ip|TcpUdp]
}

quint32 GreProtocol::protocolId(ProtocolIdType type) const {
    switch(type) {
        case ProtocolIdIp: return 47;
        default:break;
    }

    return AbstractProtocol::protocolId(type);
}
```

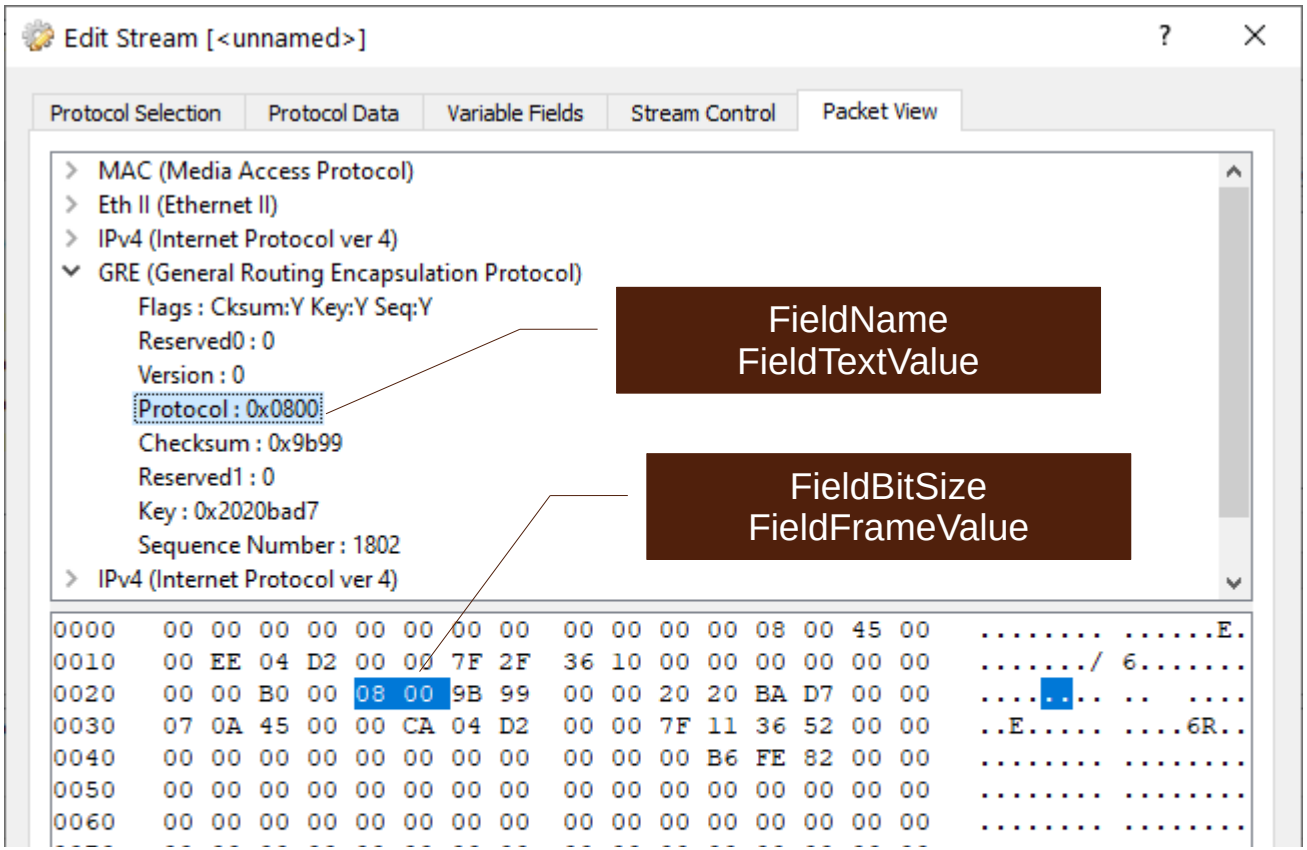
GRE Core (gre.cpp) – Field count and flags

```
int GreProtocol::fieldCount()  const {
    return gre_fieldCount;
}

AbstractProtocol::FieldFlags GreProtocol::fieldFlags(int index) const {
    AbstractProtocol::FieldFlags flags // Options: [Frame,Cksum,Meta]Field
                = AbstractProtocol::fieldFlags(index);// returns FrameField
    if (index == gre_checksum)
        flags |= CksumField;
    return flags;
}

int GreProtocol::frameFieldCount() const { // Only if no. of fields may vary
    int count = 4; // mandatory fields - flags, rsvd0, version, protocol
    if (data.flags() & GRE_FLAG_CKSUM)
        count += 2; // checksum, rsvd1
    if (data.flags() & GRE_FLAG_KEY)
        count++;
    if (data.flags() & GRE_FLAG_SEQ)
        count++;
    return count;
}
```

GRE Core (gre.cpp) – Field Data

```
QVariant GreProtocol::fieldData(int index, FieldAttrib attrib, int streamIndex) const {
    switch (index) {
        case gre_protocol: {
            quint16 protocol = payloadProtocolId(ProtocolIdEth);
            switch(attrib) {
                case FieldName: // as string
                    return QString("Protocol");
                case FieldValue: // as integer
                    return protocol;
                case FieldFrameValue: { // as a byte array in Network byte order
                    QByteArray fv;
                    fv.resize(2);
                    qToBigEndian(protocol, (uchar*) fv.data());
                    return fv;
                }
                case FieldTextValue: // value as string
                    return  QString("0x%1").arg(protocol, 4, BASE_HEX, QChar('0'));
                case FieldBitSize: // required ONLY if size is not a byte multiple
                    return 16;
                default:
                    break;
            }
            break;
        }
        // other fields ...
    }
    return AbstractProtocol::fieldData(index, attrib, streamIndex);
}
```

GRE Core (gre.cpp) – Field Data Attributes



GRE Core (gre.cpp) – Set Field Data

```
bool GreProtocol::setFieldData(int index, const QVariant &value,
        FieldAttrib attrib) {
    bool isOk = false;

    if (attrib != FieldValue)
        goto _exit;

    switch (index) {
        case gre_flags: {
            uint flags = value.toUInt(&isOk);
            if (isOk)
                data.set_flags(flags);
            break;
        }

        // ...
    }

_exit:
    return isOk;
}
```

GRE Core (gre.cpp) – Protocol Frame Size

```
//  Implement only if not a fixed size
int GreProtocol::protocolFrameSize(int /*streamIndex*/) const {
    int size = 4; // mandatory fields - flags, rsvd0, version, protocol

    if (data.flags() & GRE_FLAG_CKSUM)
        size += 4;
    if (data.flags() & GRE_FLAG_KEY)
        size += 4;
    if (data.flags() & GRE_FLAG_SEQ)
        size += 4;

    return size;
}
```

GRE Core - Registration

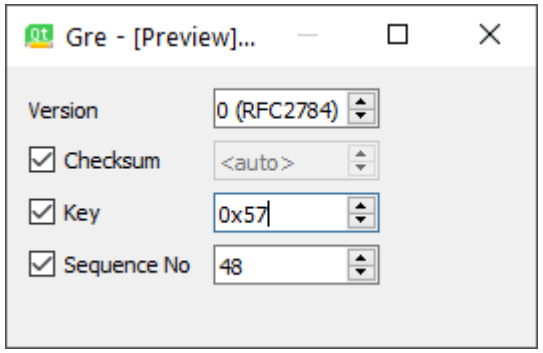
```
--- a/common/protocolmanager.cpp
+++ b/common/protocolmanager.cpp
@@ -46,6 +46,7 @@ along with this program.  If not, see <http://www.gnu.org/licenses/>
 #include "ip6over6.h"

 // L4 Protos
+#include "gre.h"
 #include "icmp.h"
 #include "igmp.h"
 #include "mld.h"
@@ -112,6 +113,8 @@ ProtocolManager::ProtocolManager()
             (void*) Ip6over6Protocol::createInstance);

     // Layer 4 Protocols
+    registerProtocol(OstProto::Protocol::kGreFieldNumber,
+            (void*) GreProtocol::createInstance);
     registerProtocol(OstProto::Protocol::kIcmpFieldNumber,
             (void*) IcmpProtocol::createInstance);
     registerProtocol(OstProto::Protocol::kIgmpFieldNumber,
```

```
--- a/common/protocol.proto
+++ b/common/protocol.proto
@@ -156,6 +156,7 @@ message Protocol {
         kIcmpFieldNumber = 402;
         kIgmpFieldNumber = 403;
         kMldFieldNumber = 404;
+        kGreFieldNumber = 405;

         kTextProtocolFieldNumber = 500;
     }
```

GRE GUI

`gre.ui, greconfig.h, greconfig.cpp`

GRE GUI (gre.ui)

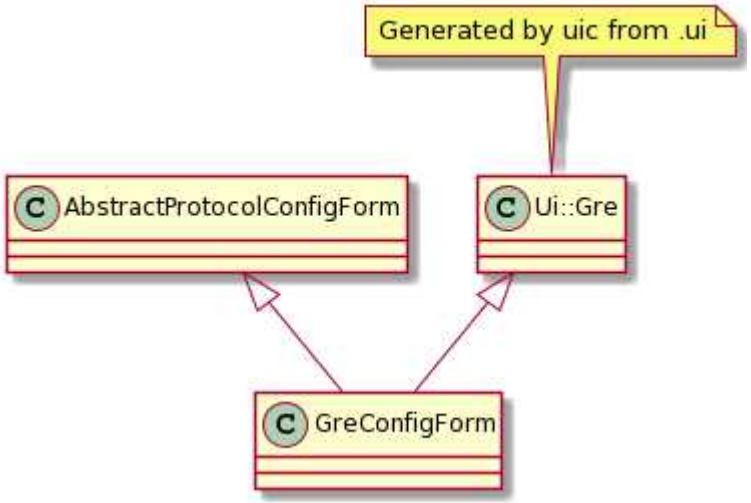


Created using Qt Designer
Saved as a .ui file (XML)

`gre.ui --> (uic) --> ui_gre.h`

```
<?xml version="1.0" encoding="UTF-8"?>
<ui version="4.0">
 <class>Gre</class>
 <widget class="QWidget" name="Gre">
  <property name="geometry">
   <rect>
    <x>0</x>
    <y>0</y>
    <width>264</width>
    <height>140</height>
   </rect>
  </property>
  <property name="windowTitle">
   <string>Gre</string>
  </property>
  <layout class="QGridLayout" name="gridLayout">
   <item row="0" column="0">
    <widget class="QLabel" name="label">
     <property name="text">
      <string>Version</string>
     </property>
    </widget>
   </item>
   <item row="0" column="1">
    <widget class="QSpinBox" name="version">
     <property name="specialValueText">
      <string>0 (RFC2784)</string>
     </property>
     <property name="maximum">
      <number>7</number>
     </property>
    </widget>
   </item>
   <!--- ... -->
 </widget>
</ui>
```

GRE GUI – Class Diagram



GRE GUI (greconfig.h)

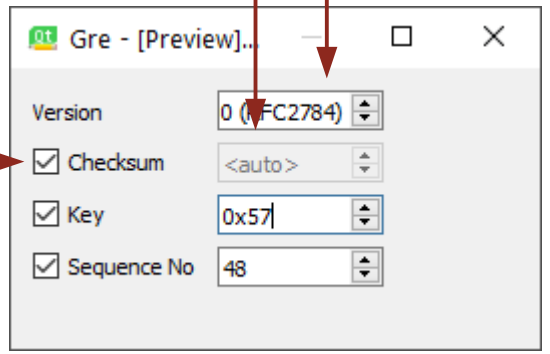
```
// Boilerplate from template

#include "abstractprotocolconfig.h"
#include "ui_gre.h"

class GreConfigForm :
    public AbstractProtocolConfigForm,
    private Ui::Gre
{
    Q_OBJECT
public:
    GreConfigForm(QWidget *parent = 0);
    virtual ~GreConfigForm();

    static GreConfigForm* createInstance();

    virtual void loadWidget(AbstractProtocol *proto);
    virtual void storeWidget(AbstractProtocol *proto);
};
```

GRE GUI (greconfig.cpp) – Boilerplate functions

```
GreConfigForm::GreConfigForm(QWidget *parent)
    : AbstractProtocolConfigForm(parent) {
    setupUi(this);
}

GreConfigForm::~GreConfigForm() {
}

GreConfigForm* GreConfigForm::createInstance() {
    return new GreConfigForm;
}
```

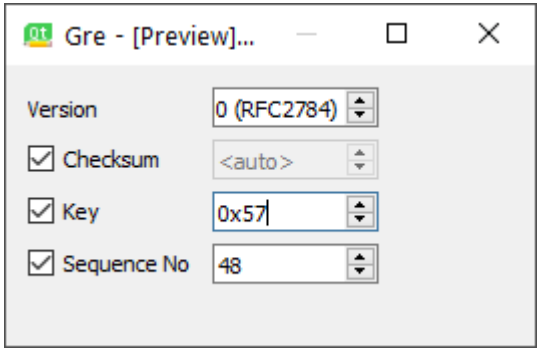
GRE GUI (greconfig.cpp) – Load widget

```
// Load widget contents from proto
void GreConfigForm::loadWidget(AbstractProtocol *proto) {
    version->setValue(
        proto->fieldData(
            GreProtocol::gre_version,
            AbstractProtocol::FieldValue
        ).toUInt());

    uint flags = proto->fieldData(GreProtocol::gre_flags,
                                  AbstractProtocol::FieldValue)
                      .toUInt();

    hasChecksum->setChecked(flags & GRE_FLAG_CKSUM);
    checksum->setValue(
        proto->fieldData(
            GreProtocol::gre_checksum,
            AbstractProtocol::FieldValue
        ).toUInt());
    // ...
}
```



GRE GUI (greconfig.cpp) – Store widget

```
// Store widget contents into proto
void GreConfigForm::storeWidget(AbstractProtocol *proto) {
    uint flags = 0;

    if (hasChecksum->isChecked())
        flags |= GRE_FLAG_CKSUM;
    if (hasKey->isChecked())
        flags |= GRE_FLAG_KEY;
    if (hasSequence->isChecked())
        flags |= GRE_FLAG_SEQ;

    proto->setFieldData(
        GreProtocol::gre_flags,
        flags);

    proto->setFieldData(
        GreProtocol::gre_version,
        version->value());

    proto->setFieldData(
        GreProtocol::gre_checksum,
        checksum->value());
    // ...
}
```



GRE GUI – Widget registration

```
--- a/common/protocolwidgetfactory.cpp
+++ b/common/protocolwidgetfactory.cpp
@@ -40,6 +40,7 @@ along with this program.  If not, see <http://www.gnu.org/licenses/>
 #include "ip6over4config.h"
 #include "ip6over6config.h"
 // L4 Protocol Widgets
+#include "greconfig.h"
 #include "icmpconfig.h"
 #include "igmpconfig.h"
 #include "mldconfig.h"
@@ -124,6 +125,9 @@ ProtocolWidgetFactory::ProtocolWidgetFactory()
             (void*) Ip6over6ConfigForm::createInstance);

     // Layer 4 Protocols
+    OstProtocolWidgetFactory->registerProtocolConfigWidget(
+            OstProto::Protocol::kGreFieldNumber,
+            (void*) GreConfigForm::createInstance);
     OstProtocolWidgetFactory->registerProtocolConfigWidget(
             OstProto::Protocol::kIcmpFieldNumber,
             (void*) IcmpConfigForm::createInstance);
```

GRE Pcap Import

`grepdml.h, grepdml.cpp`

Ostinato Intelligent PCAP Import

- Uses tshark to convert PCAP to PDML
- PDML => Packet Data Markup Language (XML)
- PDML content is essentially Wireshark protocol dissector data
  - PDML is NOT standard – may change across Wireshark/tshark versions if protocol dissector changes
- Import relies essentially on PDML field name, size, value

```
<proto name="gre" showname="Generic Routing Encapsulation (IP)" size="16" pos="34">
  <field name="gre.flags_and_version" showname="Flags and Version: 0xb000" size="2" pos="34" show="0x0000b000"
value="b000">
    <field name="gre.flags.checksum" showname="1... .... .... .... = Checksum Bit: Yes" size="2" pos="34" show="1" value="1"
unmaskedvalue="b000"/>
    <field name="gre.flags.routing" showname=".0.. .... .... .... = Routing Bit: No" size="2" pos="34" show="0" value="0"
unmaskedvalue="b000"/>
    <field name="gre.flags.key" showname="..1. .... .... .... = Key Bit: Yes" size="2" pos="34" show="1" value="1"
unmaskedvalue="b000"/>
    <field name="gre.flags.sequence_number" showname="...1 .... .... .... = Sequence Number Bit: Yes" size="2" pos="34"
show="1" value="1" unmaskedvalue="b000"/>
```

GRE Pcap Import (grepdml.h)

```
// Boilerplate from template – add more, if required

#include "pdmlprotocol.h"

class PdmlGreProtocol : public PdmlProtocol
{
public:
    virtual ~PdmlGreProtocol();

    static PdmlProtocol* createInstance();

    virtual void preProtocolHandler(QString name,
            const QXmlStreamAttributes &attributes, int expectedPos,
            OstProto::Protocol *pbProto, OstProto::Stream *stream);
    virtual void prematureEndHandler(int pos, OstProto::Protocol *pbProto,
            OstProto::Stream *stream);
    virtual void postProtocolHandler(OstProto::Protocol *pbProto,
            OstProto::Stream *stream);

    void fieldHandler(QString name, const QXmlStreamAttributes &attributes,
            OstProto::Protocol *pbProto, OstProto::Stream *stream);
    virtual void unknownFieldHandler(QString name, int pos, int size,
            const QXmlStreamAttributes &attributes,
            OstProto::Protocol *pbProto, OstProto::Stream *stream);

protected:
    PdmlGreProtocol();
};
```

GRE Pcap Import (grepdml.cpp) – 1:1 fields

```
PdmlGreProtocol::PdmlGreProtocol()
{
    ostProtoId_ = OstProto::Protocol::kGreFieldNumber;

    // Wireshark's gre.flags_and_version is NOT 1:1 with Ostinato fields

    fieldMap_.insert("gre.proto", OstProto::Gre::kProtocolTypeFieldNumber);
    fieldMap_.insert("gre.checksum", OstProto::Gre::kChecksumFieldNumber);
    fieldMap_.insert("gre.offset", OstProto::Gre::kRsvd1FieldNumber);
    fieldMap_.insert("gre.key", OstProto::Gre::kKeyFieldNumber);
    fieldMap_.insert("gre.sequence_number",
                     OstProto::Gre::kSequenceNumFieldNumber);
}
```

GRE Pcap Import (grepdml.cpp) – unknown fields

```
void PdmlGreProtocol::unknownFieldHandler(QString name,
        int pos, int size, const QXmlStreamAttributes& attributes,
        OstProto::Protocol* proto, OstProto::Stream* stream)
{
    // <field name="gre.flags_and_version"
    //        showname="Flags and Version: 0xb000" size="2" pos="34"
    //        show="0x0000b000" value="b000">
    if (name == "gre.flags_and_version") {
        bool isOk;
        quint16 flagsAndVersion = attributes.value("value")
                                            .toUInt(&isOk, kBaseHex);
        OstProto::Gre *gre = proto
                                ->MutableExtension(OstProto::gre);

        gre->set_flags(flagsAndVersion >> 12);
        gre->set_rsvd0((flagsAndVersion & 0x0FFF) >> 3);
        gre->set_version(flagsAndVersion & 0x0007);
    }
}
```

GRE Pcap Import (grepdml.cpp) – Special Handling

```
// Implement if any special handling is required

void PdmlGreProtocol::preProtocolHandler(QString name,
        const QXmlStreamAttributes& attributes,
        int expectedPos, OstProto::Protocol* pbProto,
        OstProto::Stream* stream) {
    return;
}

void PdmlGreProtocol::postProtocolHandler(OstProto::Protocol* pbProto,
        OstProto::Stream* stream) {
    return;
}

void PdmlGreProtocol::prematureEndHandler(int pos,
        OstProto::Protocol* pbProto, OstProto::Stream* stream) {
    return;
}
```

GRE Pcap Import – Registration

```
--- a/common/pdmlreader.cpp
+++ b/common/pdmlreader.cpp
@@ -28,6 +28,7 @@ along with this program.  If not, see <http://www.gnu.org/
licenses/>

 #include "arppdml.h"
 #include "eth2pdml.h"
+#include "grepdml.h"
 #include "llcpdml.h"
 #include "icmppdml.h"
 #include "icmp6pdml.h"
@@ -59,6 +60,7 @@ PdmlReader::PdmlReader(OstProto::StreamConfigList
*streams)

     factory_.insert("arp", PdmlArpProtocol::createInstance);
     factory_.insert("eth", PdmlEthProtocol::createInstance);
+    factory_.insert("gre", PdmlGreProtocol::createInstance);
     factory_.insert("http", PdmlTextProtocol::createInstance);
     factory_.insert("icmp", PdmlIcmpProtocol::createInstance);
     factory_.insert("icmpv6", PdmlIcmp6Protocol::createInstance);
```

More Info

- GitHub Repo
  https://github.com/pstavirs/ostinato
- Full code of GRE Protocol Builder - see GitHub PR
  https://github.com/pstavirs/ostinato/pull/336
- Protocol Builder Documentation
  https://devguide.ostinato.org/ProtocolBuilderHOWTO.html

- Slides and Video of this talk
  https://ostinato.org/docs/fosdem2021

Thank You!

Questions?