Passive Network Analysis Using Libtrace

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Introductions

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  - Libtrace developer since 2005
- Tony McGregor
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  - Former head of NLANR Active Measurement Project
  - Keynote speaker at PDCAT

Outline

- Introduction and Basics
- The Libtrace Tools
- Simple Libtrace Programming
- Advanced Topics

Part One

- Introduction to Passive Measurement
- Programming Issues
- Introducing Libtrace
- A Brief History Lesson
- Acquiring and Installing Libtrace
- Libtrace Basics: URIs
- Libtrace Basics: BPF filters

Passive Measurement

- Use existing network traffic to analyse network behaviour
  - No artificial “measurement” traffic
- Can be divided into two principal steps
  - Capture – reading data off the network
  - Analysis – applying metrics to the data
- We're going to focus on measurement at the packet level

Packet Capture

- Hardware
  - Endace DAG cards
- Software
  - PCAP (tcpdump)
- Kernel
  - Linux native

Packet Capture

- A header is prepended to each captured packet
  - Timestamps
  - Packet length
- Header structure differs for each capture format
  - Timestamp format can be different too

Packet Capture

- Example: ERF header used by DAG

<table>
<tr><td colspan="3">Timestamp</td></tr>
<tr><td colspan="3">Timestamp</td></tr>
<tr><td>Frame Type</td><td>Flags</td><td>Record Length</td></tr>
<tr><td colspan="2">Loss Counter</td><td>Wire Length</td></tr>
</table>

- Example: PCAP header

<table>
<tr><td colspan="2">Timestamp</td></tr>
<tr><td colspan="2">Timestamp</td></tr>
<tr><td>Capture Length</td><td>Wire Length</td></tr>
</table>

Packet Traces

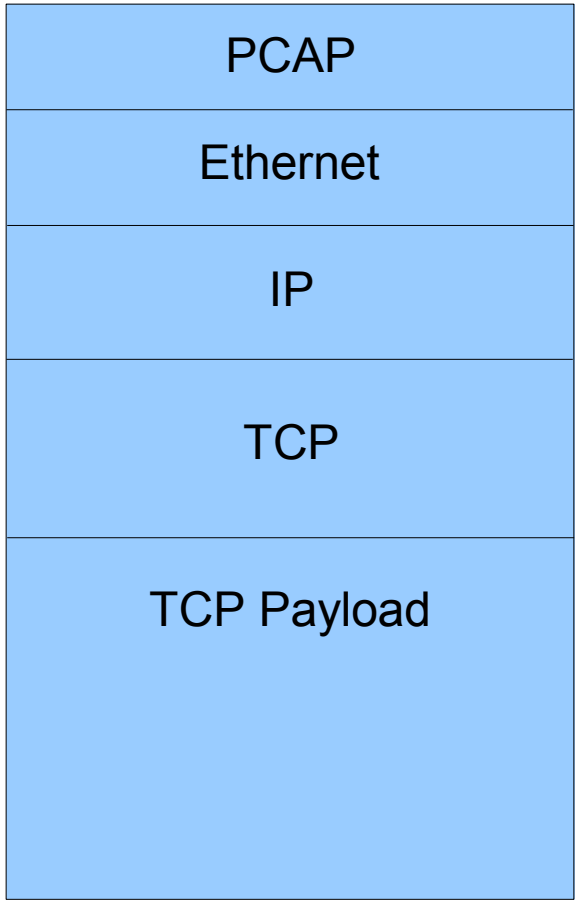
- Captured packets can be written to disk to create a trace
  - Packets are in chronological order
  - Capture format header is retained on each packet
- Analysis is repeatable
  - Errors in analysis technique can be corrected
  - Interesting behaviour can be investigated further
- Collaboration with other researchers
  - WITS - http://www.wand.net.nz/wits/
  - Datcat - http://www.datcat.org/
  - CRAWDAD - http://crawdad.cs.dartmouth.edu/

Packet Traces

- Full payload capture
  - All of the packet is retained
  - Simple to implement
  - Investigating application behaviour is easier
- Disadvantages
  - Privacy concerns due to capturing user data
  - Trace files are extremely large

Packet Traces

- Example – blue area represents the captured data

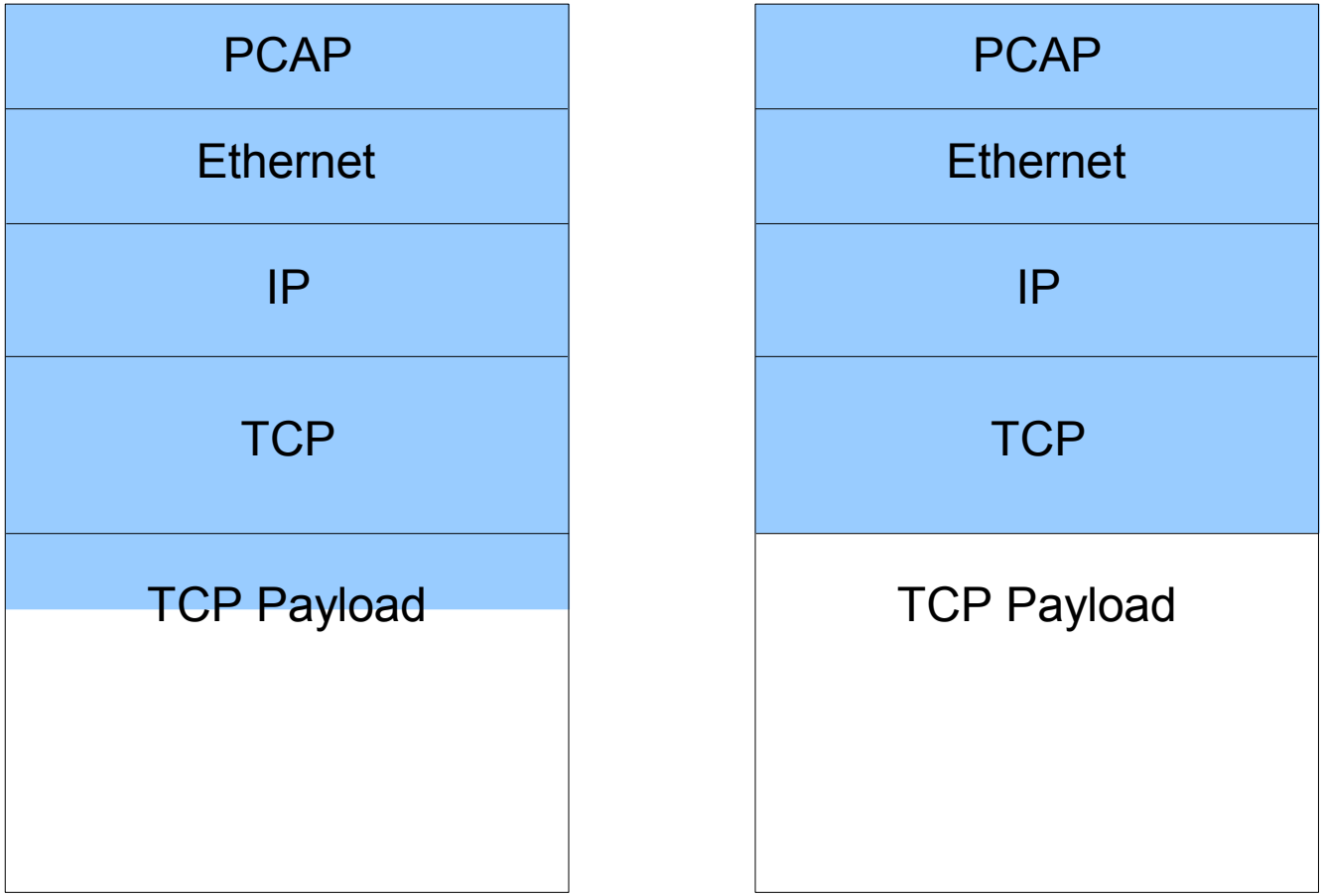


Packet Traces

- Header capture
  - Captured packets are truncated (snapped) to remove user payload
    - Fixed length snapping vs header-based snapping
  - Traces require less space
  - Most pertinent information is in the headers

Packet Traces

- Example – fixed length (left) vs header snapping (right)



Passive Analysis

- Simple examples
  - Counting packets or bytes
  - Examining TCP/IP headers
- Advanced ideas
  - TCP object extraction
  - Application analysis, e.g. HTTP
  - Visualisation

Passive Analysis

- Real-time
  - Capture process reads straight off a network interface
  - Performance is critical
  - Most practical applications are real-time
    - e.g. anomaly detection, visualisation

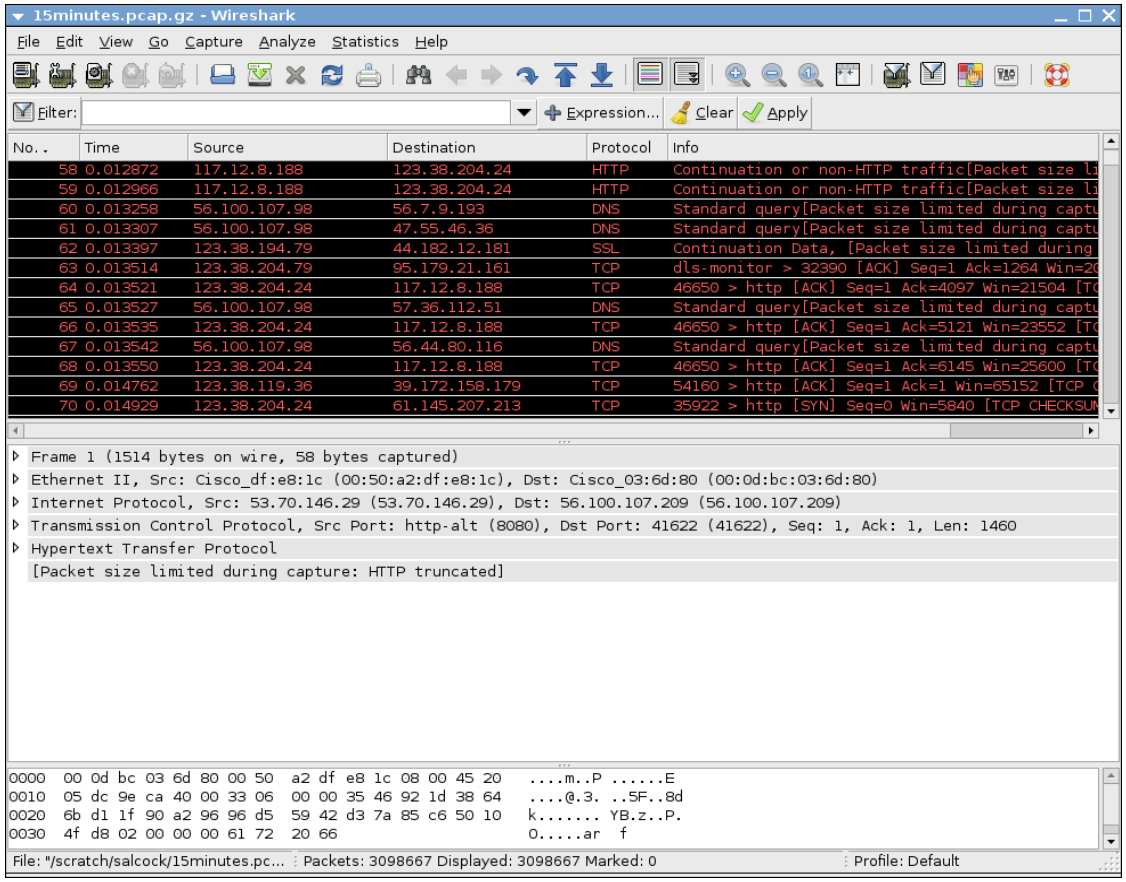
- Off-line
  - Replace the capture step with reading from a trace file
  - Best for resource-intensive analysis
  - Many research applications can be done solely off-line

Passive Analysis

- Use existing tools
  - Examples: wireshark, tcptrace
  - Designed to perform a specific set of tasks
- Develop new analysis tools
  - Particularly common for research applications

Passive Analysis

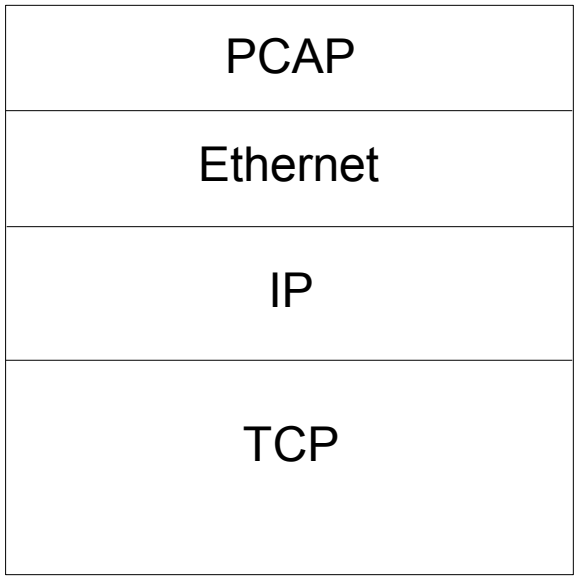
- Example of an existing tool: wireshark



Development Issues

- Aim is to count packets using TCP port 80
  - Should be easy, right?

- Standard TCP/IP packet captured using PCAP from an Ethernet link



Development Issues

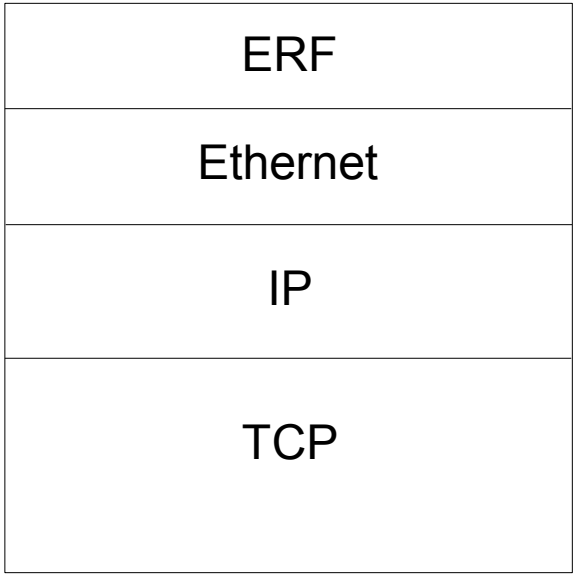
- The general case is simple
  - Step through the preceding headers to reach the TCP header
    - Be careful of the variable length IP header!
  - Check the port numbers inside the TCP header
  - Increment counter if necessary
  - Move onto next packet
    - PCAP header will tell us how far we need to skip ahead

Development Issues

- What about the special cases?
  - The packet isn't a TCP packet, e.g. UDP or ICMP
  - The packet isn't an IP packet, e.g. ARP
  - The packet was truncated before the TCP header
  - The packet was truncated part-way through the TCP header
  - The packet was fragmented
    - TCP header could be in a different fragment
  - Note that this is not a comprehensive list!

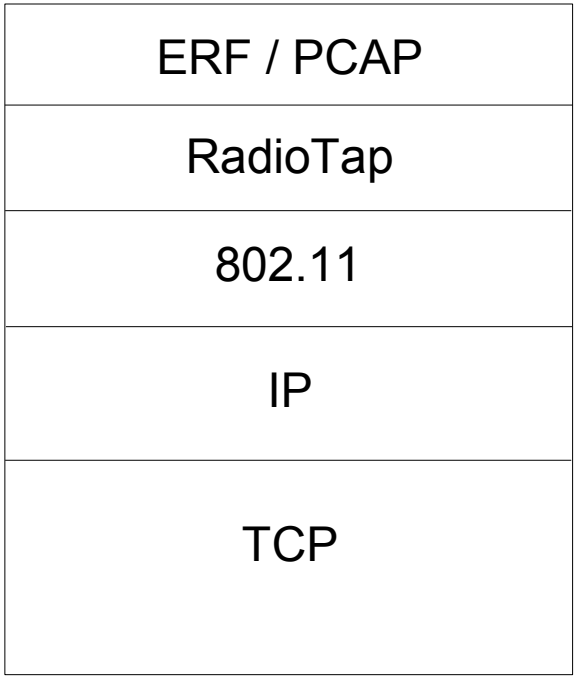
Development Issues

- Try our analysis on another trace set
  - What if the traces use the ERF format instead of PCAP?
  - Update program to support new capture format



Development Issues

- Applying our analysis to a trace from a wireless link
  - Need to add code to detect and skip over 802.11 headers
  - Still need to keep our old code for Ethernet as well

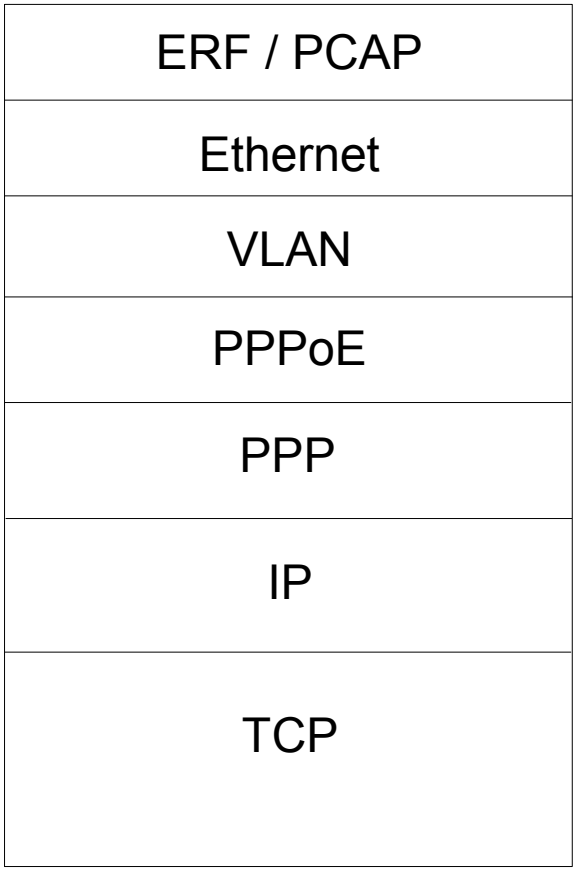


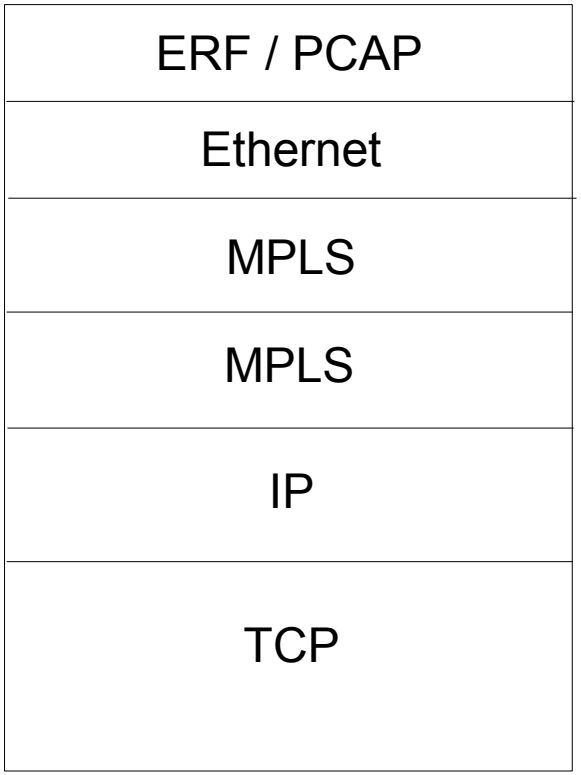
Development Issues

- Wireless introduces an entirely new set of problems
  - 802.11 header varies in length
  - RadioTap header is not always present
    - Might be an entirely different header altogether, e.g. Prism
    - Might be no header at all before the 802.11 header
  - Frame corruption
  - Fragmentation can also occur at the 802.11 level
  - Once again, not a comprehensive list

Development Issues

- Other link layer protocols





Development Issues

- What about running our analysis on a live capture?
  - Live capture APIs add an extra level of complexity
  - Buffer management
  - Code needs to be efficient

Summary

- Developing a portable analysis tool is very difficult
  - Subtle differences between each format header
  - Link layer encapsulation is a nightmare
  - Live capture formats are particularly difficult to code
  - Huge variety of special cases and banana skins

- Wouldn't it be nice if someone...
  - did all the tricky programming for us
  - wrapped it in a nice API that abstracted away all the nasty details
  - gave it all away for free
  - was willing to show you how to use it

Introducing Libtrace

- Packet capture and analysis library
- Developed by WAND (University of Waikato)
  - Written in C, but we have added Ruby bindings
- Design aimed to resolve all these issues
  - Make passive analysis simple and reduce code replication
- Supports reading and writing of trace files

Libtrace Features

- Capture format agnostic
  - The same libtrace program works on any supported capture format
  - No difference between live and off-line capture formats
  - Developmental advantages
    - Analysis programs can be tested off-line before running live

Libtrace Features

- Protocol details are dealt with internally
  - Direct access to each protocol layer
    - e.g. `trace_get_tcp()` jumps straight to the TCP header
  - Handles a variety of link layer protocols including ...
    - Ethernet
    - 802.11 wireless
    - VLAN
    - MPLS

Libtrace Features

- Bundled with a suite of tools to perform common tasks
  - Dumping packet contents
  - Trace splitting and filtering
  - Converting between trace formats
  - Statistical reports

History

- Began as a library for live analysis from Waikato capture
  - Reading ERF packets received via TCP
- Extended to read from trace files
  - Using zlib to read compressed trace files
- Writing analysis code was involving lots of copy / paste
  - Add commonly used functions to the library
- Added support for PCAP using libpcap

History

- Libtrace 2 (2004)
  - Began as a major API clean-up
- Many features were added throughout its lifetime
  - Support for writing traces
  - Libtrace tools
  - Support for many new protocols and link types
  - Support for new capture formats, e.g. Auckland trace formats
  - Easy conversion between capture formats
  - Packet dumping library
  - Internal error system, e.g. trace_perror()

History

- Libtrace 3 (2006)
  - Zero-copy for live capture formats
    - Significant performance improvements for live capture
  - Native pcap file support
  - Added configuration system for captures
    - Snap length, BPF filters, etc.
  - Decode IPv6 headers
  - Comprehensive wireless support
  - Even better error handling
  - Cleaned up API (again!)
  - Polished libtrace tools

Present Day

- Current libtrace version is 3.0.5
  - Available from http://research.wand.net.nz/software/libtrace.php
- Open source
  - GPL license
- Operating Systems
  - Linux
  - FreeBSD
  - MacOS
  - Windows is unsupported, but we have built DLLs in the past

Installing Libtrace

- Requirements
  - automake-1.9 or later
  - libpcap-0.8 or later
  - flex and bison
- Strongly recommended
  - zlib-dev
- Required for DAG capture
  - DAG libraries (provided with DAG hardware)

Installing Libtrace

```
./configure
make
make install
```

- Installs to /usr/local/lib by default
  - Append `--prefix=DIR` option to `./configure` to change

- `./configure --help` for a full list of options

Libtrace URIs

- URIs are used to tell libtrace programs the format and location of a trace or live capture

- All URIs resemble:

  <format>:<location>

Supported Capture Formats

Format	Base URI	Example	Write
DAG	dag	dag:/dev/dag0	No
ERF	erf	erf:/trace/example.erf.gz	Yes
PCAP interface	pcapint	pcapint:eth0	Yes
PCAP file	pcapfile	pcapfile:/trace/example.pcap.gz	Yes
Native Linux	int	int:eth0	Yes
Native BSD	bpf	bpf:eth0	No
TSH	tsh	tsh:/trace/example.tsh.gz	No
RT protocol	rt	rt:localhost:4500	No
Legacy ATM	legacyatm	legacyatm:/trace/example.atm.gz	No
Legacy Ethernet	legacyeth	legacyeth:/trace/example.eth.gz	No
Legacy PoS	legacypos	legacypos:/trace/example.pos.gz	No
ATM Cell Header	atmhdr	atmhdr:/trace/example.atmhdr.gz	No
FR+	fr+	fr+:/trace/example.fr.gz	No

BPF Filters

- Libtrace supports using BPF expressions to filter traffic
  - Commonly used in PCAP (tcpdump)

- Examples
  - “tcp port 80”
  - “src host 192.168.2.1 and src host 192.168.2.2”
  - “less 100”
  - `man tcpdump` for more details

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