



it's about time



Technical Whitepaper

# Kdb+ and WebSockets

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## Kdb+ and WebSockets

Since the release of kdb+ 3.0, it has been possible to make use of [WebSockets](#)<sup>1</sup> when connecting to a kdb+ process. This has significant implications for how we can build front-end applications that use a kdb+ back-end, in particular for applications wanting to display real-time information.

WebSockets are supported by most modern browsers and thus make it possible to hook a web application up directly to a kdb+ process to allow real-time communication over a persistent connection. This gives us the ability to build a pure HTML5 real-time web application which can connect to kdb+ through JavaScript, which is native to web browsers.

Using web applications to build GUIs for kdb+ applications is becoming increasingly popular. Only a web browser is required to run the GUI, so it is OS independent. This means that when developing the GUI, only one codebase is required for all platforms and maintenance and upgrades are much easier and efficient to perform.

This paper introduces what WebSockets are and what benefits they hold over standard HTTP. It takes the reader through the set-up of a simple web page that uses WebSockets to connect to a kdb+ process, the steps involved in passing data through the connection, and the various methods for converting data between kdb+ and JavaScript.

An earlier version of this paper was published in October 2014. Kdb+ has been enhanced since then to support the growing popularity of WebSockets and JSON. As part of this revision, the paper now also documents new message handlers for opening and closing WebSocket connections in section 3.3, and debugging techniques that can be used to view traffic over these connections in section 5.

The paper finishes with a full working example (including code) of a simple Web application which uses kdb+ to provide real-time updating of tables based on user queries.

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1. <https://en.wikipedia.org/wiki/WebSocket>

## HTML, CSS and JavaScript

As well as q, this paper makes significant use of HTML, CSS and JavaScript. A basic understanding of these will be necessary to take full advantage of this paper, though any complex structures will be examined here in detail. For a crash course on the above languages, please refer to the following resources:

- [w3schools.com](http://w3schools.com)<sup>2</sup>
- [codecademy.com](http://codecademy.com)<sup>3</sup>

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2. <http://www.w3schools.com/>

3. <http://www.codecademy.com/>

## What are WebSockets?

WebSockets were a long-awaited evolution in client and web server communication technology. They provide a protocol between a client and server which runs over a persistent TCP connection. The client-server connection can be kept open as long as needed and can be closed by either the client or the server. This open connection allows bi-directional, full-duplex messages to be sent over the single TCP socket connection – the connection allows data transfer in both directions, and both client and server can send messages simultaneously. All messages sent across a WebSocket connection are asynchronous.

Without WebSockets, bi-directional messaging can be forced by having distinct HTTP calls for both the client sending requests and the server publishing the responses and updates. This requires either the client to keep a mapping between outgoing and incoming messages, or the use of a proxy server in between the client and server (known as HTTP tunneling). WebSockets simplify this communication by providing a single connection which both client and server can send messages across.

WebSockets were designed to be implemented in web browsers and web servers, but they can be used by any client or server application. The ability for bi-directional real-time functionality means it provides a basis for creating real-time applications on both web and mobile platforms. The WebSocket API and Protocol have both been standardized by W3C and the IETF respectively.

### Why not just use `.z.ph`?

It has previously been possible to connect to a kdb+ process using HTTP. HTTP requests could be processed using the `.z.ph` and `.z.pp` handlers. To illustrate this, simply start up a `q` process with an open port and then type the `hostname:port` into your web browser. This will give a very basic view of the `q` process.

Straight out of the box, this is very simple and provides a useful interface for viewing data and running basic queries without being limited to the character limits of a `q` console. If, however, you want to do more than just simple analysis on the `q` process, this method presents a few drawbacks:

1. Customization is quite a complicated process that requires you to manipulate the functions in the `.h` namespace which form the basis of the in-built HTTP server code. The HTML markup is generated entirely by the `q` process.

2. Data must be requested by the browser, so some form of polling must occur in order to update the webpage. This makes the viewing of real-time data impossible without the continuous polling of the kdb+ server.
3. `.z.ph` uses synchronous messaging, and the webpage is effectively refreshed every time a query is sent.

Instead of relying on `.z.ph` to serve the entire web page, an application could make use of AJAX techniques to send asynchronous GET and POST requests to a kdb+ server. `.z.ph` and `.z.pp` can be modified to handle these requests. AJAX (Asynchronous JavaScript And XML) is a descriptive name that covers a range of web development techniques that can be used to provide asynchronous messaging between a web application and server.

This allows requests to be made by the client in the background without having to reload the web page, and as there is no reliance on `.z.ph` to generate the HTML markup, the application can be fully customized independently of the kdb+ process. In order to receive updates, the application will still have to poll the server, which is not ideal for real-time data. The full implementation of this method is beyond the scope of this whitepaper.

As WebSocket connections are persistent, the server is able to push updates to the client rather than relying on the client to poll for the information. Additionally, while each HTTP request and response must include a TCP header, WebSockets only require this header to be sent during the initial handshake.

# Connecting to kdb+ using WebSockets

## The handshake

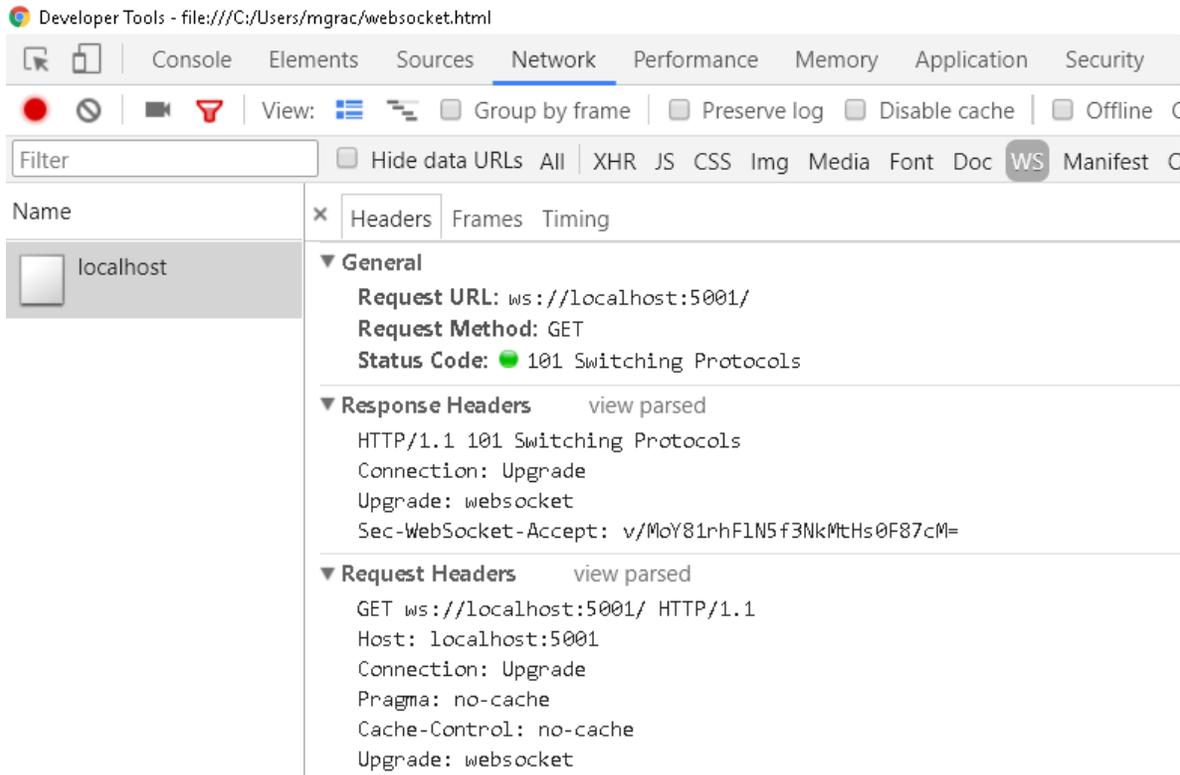
In order to initialise a WebSocket connection, a WebSocket ‘handshake’ must be successfully made between the client and server processes. First, the client sends a HTTP request to the server to upgrade from the HTTP protocol to the WebSocket protocol:

```
// Client WebSocket request header</p>
GET /text HTTP/1.1
Host: localhost:5001
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Key: xc0DPEL132m1MtGdbWJPGQ==
Sec-WebSocket-Version: 13
```

The server then sends a HTTP response indicating that the protocol upgrade was successful:

```
// Server WebSocket response header
HTTP/1.1 101 Switching Protocols
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Accept: 1thgMR0s9y10W0Mkc2WUWGRzWdY=
```

The above handshake request and response details can be found within a browser’s dev tools. Google Chrome’s developer tools can be opened with the F12 key and any information on a pages network operations can found within its *Network* tab. Here you can click on *WS* to filter out just the WebSocket connections and then select a specific WebSocket connection to see a headers section detailing its request and response headers and perhaps, more importantly, see a *Frames* section which can be used to monitor traffic sent over the connection in real time. We will revisit the *Frames* section later.



*The Network tab in Chrome Developer Tools*

## **.z.ws message handler**

Like the `.z.ph` HTTP GET handler, `kdb+` has a separate message handler for WebSockets called `.z.ws`, meaning all incoming WebSocket messages will be processed by this function. There is no default definition of `.z.ws`; it should be customized by the developer to handle the incoming messages as required. Later, several examples of a customized `.z.ws` handler will be shown, but initially, we will look at a very basic definition:

```
q).z.ws:{neg[.z.w].Q.s value x;}
```

For now, let's assume that `x` (the query from the client) is being passed in as a string. `value x` simply evaluates the query, and passing this into `.Q.s` will present the result in console output format (i.e. plain text).

As mentioned before, all messages passed through a WebSocket connection are asynchronous. This means that we must handle the server response within the `.z.ws` message handler. `neg[.z.w]` does this by asynchronously pushing the results back to the handle which raised the request.

From the server side, using `neg[.z.w]` within the handler will push the result back to the client once it has been evaluated. The client does not wait for a response and instead

the open WebSocket connection will receive the response some time later, so we must handle this on the client side as well.

Fortunately, JavaScript has a native WebSocket API which allows us to handle this relatively easily. The main parts of the JavaScript API are explained below.

```
<script type="text/javascript">
  function connect(){
    if ("WebSocket" in window){ // check if WebSockets supported
      // open a WebSocket
      var ws = new WebSocket("ws://host:port");
      ws.onopen = function(){
        // called upon successful WebSocket connection
      };
      ws.onmessage = function(msg){
        // called when the client receives a message
      };
      ws.onclose = function(){
        // called when WebSocket is closed
      };
    }
    else {
      // the browser doesn't support WebSockets
    }
  }
  ws.send(msg) // function to handle sending a message
</script>
```

### **.z.w0 and .z.wc message handlers**

The `.z.w0` and `.z.wc` message handlers were introduced in kdb+ version 3.3 (2014.11.26) to be evaluated whenever a WebSocket connection is opened (`.z.w0`) or closed (`.z.wc`). Prior to this version, `.z.pc` and `.z.p0` provide an alternative solution however, these handle the opening and closing of all connections over a port and don't distinguish WebSocket connections.

The `.z.w0` handler, much like its `.z.p0` counterpart, is called when the connection is initialized and after it has been validated against any `-u/-U` and/or `.z.pw` checks in place. Neither `.z.w0` nor `.z.wc` has a default definition, so they should be customized by the developer accordingly. Typical usage of these handlers is to maintain information on active WebSocket connections as demonstrated below:

```

q)\p 5001
q)activeWSConnections: ([] handle:(); connectTime:())

//x argument supplied to .z.wc & .z.wo is the connection handle
q).z.wo:{`activeWSConnections upsert (x;.z.t)}
q).z.wc:{ delete from `activeWSConnections where handle =x}

//websocket connects
q)activeWSConnections
handle connectTime
-----
548 13:15:24.737

//websocket disconnects
q)activeWSConnections
handle connectTime
-----

```

## Simple example

Here is an example of a simple client application connecting to a kdb+ server using a WebSocket. This is a slightly modified version of the example in the Cookbook [WebSocket article](#)<sup>4</sup>.

First, start up a kdb+ server and set our `.z.ws` handler. Here we will also add some error trapping to the handler to send any error message to the client.

```

q)\p 5001
q).z.ws:{neg[.z.w].Q.s @[value;x;{'$ """,x}]}

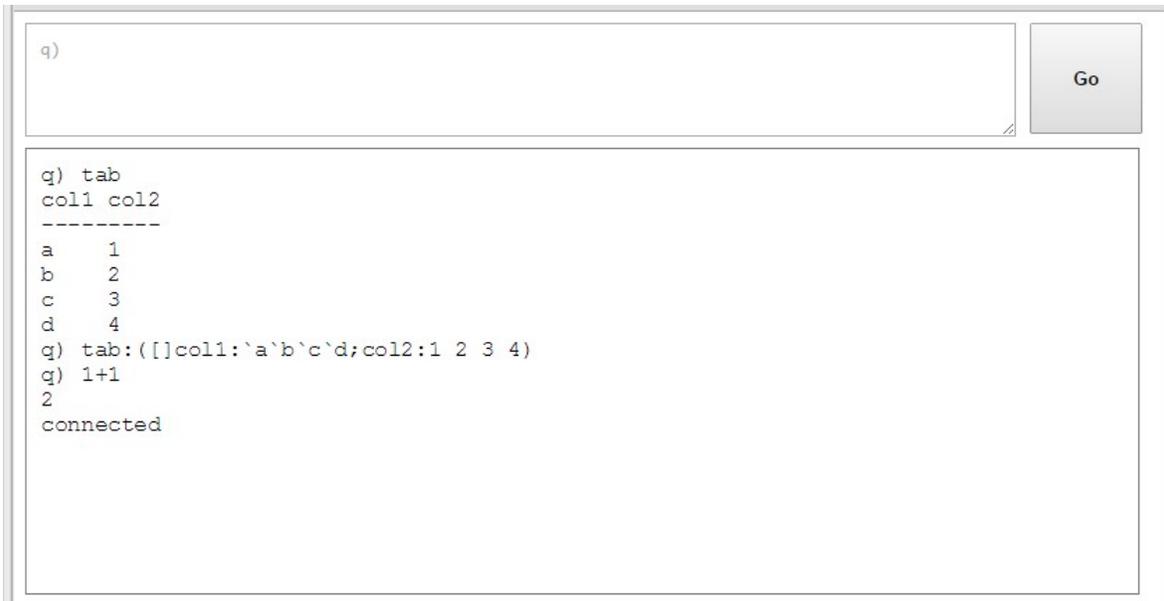
```

Next, we create an HTML document that we will use to connect to our kdb+ server. The code for creating this is given in Appendix A and should be copied into a text editor and saved as an HTML file, which can then be read in any modern web browser.

In our HTML code, we define the elements that will capture input and display output, apply some basic stylings to those elements and supply the JavaScript that will send our input to the server and handle the response it gets back. This web application will function like a q console in that we can write some q commands in its input box, send that input as a string to the server by clicking a button and then see the returned result produced by the server evaluating those input commands.

---

4. <http://code.kx.com/q/cookbook/websockets>



The screenshot shows a web console application with an input field containing 'q)' and a 'Go' button. Below the input field, the output of the command is displayed in a monospaced font:

```
q) tab
col1 col2
-----
a     1
b     2
c     3
d     4
q) tab:([[col1:`a`b`c`d;col2:1 2 3 4)
q) 1+1
2
connected
```

*A web console application which allows q commands to be executed from the browser*

## Pushing data to the client using neg[h]

Above, we have used `neg[.z.w]` within the `.z.ws` handler to return the result to the client immediately after it is received and evaluated. But in some situations, we don't want to just provide a response, but rather set up a subscription that continually pushes data through our WebSocket connection.

As the WebSocket is persistent and obeys normal IPC protocol, we can push data through it asynchronously at any time using `neg[h]`, where `h` is the WebSocket handle. To see this, in the input box of the example application above, type the following code and click *Go*.

```
q).z.ts:{{[x;y]neg[x].Q.s .z.T}[.z.w]; system"t 1000"
```

You should now see the current time being output every second, without the browser having to poll for the data.

## Converting kdb+ to JSON

Converting kdb+ into string format using `.Q.s` means that not only is the message limited by the console size, but also that, as the client is receiving plain text, the data will be unstructured and very difficult to parse into something that can be manipulated by the client.

JavaScript has a built-in technology called JSON (JavaScript Object Notation) which can be used to create JavaScript objects in memory to store data. These objects are collections of name/value pairs which can be easily accessed by JavaScript and used to build the data structures displayed on the web page.

We want to make use of JSON to hold our data so that we can easily display and manipulate our data on the client. There is a very important relationship between kdb+ and JSON – kdb+ dictionaries and JSON objects are comparable. This means that we can parse our kdb+ data into JSON structures very easily, with tables just becoming arrays of JSON objects.

Depending on the application, it may be of benefit to do this conversion on the server side within the q process, or on the client-side in the JavaScript code. We will explore the two options along with an example to show both in action.

### **Using .j functions within a q process (server-side parsing)**

Kdb+ 3.3 introduced native functions for translating between kdb+ and JSON format. This resulted in a 50-100× speedup compared to previous functionality, and the new versions can also process Unicode.

There are two main functions that we will make use of:

- `.j.j` parses kdb+ into a JSON string
- `.j.k` parses a JSON string into kdb+

```

q)tab:([]col1:`a`b`c`d;col2:1 2 3 4)
q)tab
col1 col2
-----
a     1
b     2
c     3
d     4
q).j.j tab
"[\\"col1\\":\\"a\\",\\"col2\\":1},{\\"col1\\":\\"b\\",\\"col2\\":2},{\\"col1\\":\\"c\\",\\"c..
q).j.k "{\\"a\\":1,\\"b\\":2,\\"c\\":3,\\"d\\":4}"
a| 1
b| 2
c| 3
d| 4

```

Here is an example of how we can use this to manipulate data in our web app. First set up our server and use `.j.j` to convert the kdb+ output to JSON:

```

q)\p 5001
q).z.ws:{neg[.z.w].j.j @[value;x;{'$ """,x}];}

```

‘Above’ we used the `SimpleDemo.html` file given in ‘Appendix A’, which includes some code to handle a plain-text response and append it to the screen:

```

/*
   when a message is received, prepend the message to the display area
   along with the input command
*/
ws.onmessage=function(e){
  /*
     the message is in plain text, so we need to convert ' ' to '&nbsp;'
     and '\n' to '<br />' in order to display spaces and newlines correctly
     within the HTML markup
  */
  var formattedResponse = e.data.replace(/ /g, '&nbsp;').replace(/\n/g, '<br />');
  output.innerHTML = cmd + formattedResponse + output.innerHTML;
  cmd="";
}

```

We can now rewrite the `ws.onmessage` JavaScript function from this example to handle the messages coming through as JSON strings rather than just plain text.

```

ws.onmessage=function(e){
  /*parse the JSON string into a JSON object using JSON.parse */
  var outputHTML,data = JSON.parse(e.data);
  if (typeof data == "object") {
    /* if an object, then message must be a table or a dictionary */
    if (data.length) {
      /*if object has a length then it is a table*/
      outputHTML = generateTableHTML(data);
    } else {
      /*
        if object has no length, it is a dictionary,
        in this case we will iterate over the keys to print
        the key|value pairs as would be displayed in a q console
      */
      for (var x in data)
        outputHTML += x + " | " + data[x] + "<br />";
    }
  } else {
    /* if not an object, then message must have simple data structure*/
    outputHTML = data;
  };
  output.innerHTML = cmd + outputHTML + "<br />" + output.innerHTML;
}

```

Whenever we handle a table in this example you will notice we call a function named `generateHTML`. This is a simple function we wrote to loop over each object in the array of objects that we now know represents a table and wrap each inner value in HTML table markup. This is in a separate function because we will reuse this functionality later and having it in a separate function makes it easier to copy and reuse in other applications.

```

function generateTableHTML(data){
  /* we will iterate through the object wrapping it in the HTML table tags */
  var tableHTML = '<table border="1"><tr>';
  for (var x in data[0]) {
    /* loop through the keys to create the table headers */
    tableHTML += '<th>' + x + '</th>';
  }
  tableHTML += '</tr>';
  for (var i = 0 i < data.length; i++) {
    /* loop through the rows, putting tags around each col value */
    tableHTML += '<tr>';
    for (var x in data[0]) {
      tableHTML += '<td>' + data[i][x] + '</td>';
    }
    tableHTML += '</tr>';
  }
  tableHTML += '</table>';
  return tableHTML;
}

```

With our improvements in place, you can see that it gives the same web console application as before. The distinction, however, is that we are now handling JSON objects which are easier to manipulate than strings of plain text. The JavaScript code will now be aware of data type information which is not the case with plain strings and could use that information to perform more complex operations like filtering data or populating charts.

Using the `.j` functions within the `q` process is very straightforward, and if it is suitable for the application to transfer messages across the WebSocket as strings, this can be a good solution. However, in some cases, it may be preferable to serialize the data into binary format before transmitting it across the connection.

### Using `c.js` within JavaScript (client-side parsing)

Instead of parsing the data within the `kdb+` server using `.j` functions, we could instead use `-8!` to serialize the data into `kdb+` binary form and then deserialize it on the client side directly into a JSON object. With client machines generally being a lot more powerful than in the past, it is reasonable to provide the client-side JavaScript code with some extra workload.

This approach requires a little more understanding of JavaScript. However, Kx provides the script `c.js` which contains the functionality to serialize and deserialize data on the client side. The `deserialize` function converts `kdb+` binary data into JSON, while the `serialize` function will convert our message into `kdb+` binary format before sending it to the server. `c.js` can be found on GitHub at: [KxSystems/kdb/c/c.js](https://github.com/KxSystems/kdb/c/c.js)<sup>7</sup>

The previous section showed how we can parse `q` structures into JSON strings and send them to our client. In this example, we will instead do all of the parsing on the client side to produce the same result. The client will send strings to the server, but the server will send serialized data back to the client. Outgoing messages are serialized using the `-8!` operator:

```
q)\p 5001
q).z.ws:{neg[.z.w] -8! @[value;x;{'$"',x}]}
```

We need to make a few adjustments to our JavaScript code in order to handle the serialized responses. Firstly, we need to load the `c.js` script into our web page by downloading the `c.js` file to the same directory as our HTML document, and include the below import just before our main set of `<script>` tags.

---

7. <https://github.com/KxSystems/kdb/blob/master/c/c.js>

```
<script src="c.js"></script>
```

When we define our WebSocket connection, we need to tell the JavaScript code to expect the messages to be coming through in binary. For this we set `ws.binaryType` to `'arraybuffer'`. Place this line on the line after we have set up the new WebSocket connection.

```
ws = new WebSocket("ws://localhost:5001/");  
ws.binaryType = 'arraybuffer';
```

Next, we need to edit the `ws.onmessage` function. As we are deserializing the message straight into JSON, we do not need to use the `JSON.parse` function. Instead, we simply replace it with the `deserialize` function provided in `c.js`.

```
var outputHTML,data = deserialize(e.data);
```

The rest of `ws.onmessage` should be identical to the example in the previous section and should work exactly as it did before. We could also decide we want to serialize the message that we send to the server from the client using the `serialize` function.

```
ws.send(serialize(input.value));
```

This would then require that we update `.z.ws` to deserialize the message back into a string using `-9!` so that it can then be evaluated.

```
q).z.ws:{neg[.z.w] -8! @[value;-9!x;{'$ ""',x}]}
```

🌐 Reference: [IPC](http://code.kx.com/q/ref/ipc)<sup>8</sup> for more on serialization

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8. <http://code.kx.com/q/ref/ipc>

## Viewing traffic over a WebSocket connection

When working with WebSockets sometimes we may need to view the messages that are being sent over a WebSocket connection for debugging purposes. We can do this by inspecting the *Network* tab in our browser's developer tools. We are going to use Google Chrome for the demonstration of this, but most modern browsers will also implement similar network-monitoring tools.

In 'The handshake', we looked at the headers associated with a WebSocket connection. Beside the *Headers* section, there is a *Frames* tab that displays what messages have been sent and received, the time they happened, and how many characters long those messages were. The figure below shows us the traffic conducted while using our earlier web console application.

Name	Headers	Frames	Timing
localhost	All	Enter regex, for example: (web)?socket	
		Data	Length Time
		↑1+1	3 17:08:42.956
		↓2	1 17:08:42.960
		↑tab:([col1:1,2,3; col2:a`b`c); tab	36 17:09:28.671
		↓[{"col1":1,"col2":"a"}, {"col1":2,"col2":"b"}, {"col1":3,"col2":"c"}]	71 17:09:28.675
		↑dict:a`b`c!(1,2,3); dict	25 17:10:05.383
		↓{"a":1,"b":2,"c":3}	19 17:10:05.393
		↑dict	4 17:15:34.734
		↓Binary Frame (Opcode 2)	51 17:15:34.741

*The sent and received messages over a connection as displayed in Google Chrome's Network tab*

You can see above that the messages in green are query strings that we are sending to the server and the messages in white are the JSON strings we are getting back. The last line shows us a different response from the server. At this point, the `.z.ws` message handler was modified slightly. Instead of using `.j.j` before sending back the data, it was changed to serialize it using `-8!` instead. The binary frame that we see is simply the serialized response we are getting back. It is important to note when sending serialized data we cannot view the message again until it has been received and deserialized.

## WebSocket security

Security is one of the biggest concerns in any system. It is of the utmost importance that, especially when dealing with sensitive financial information, users only have access to view and edit data they are allowed to see.

The methods used to protect kdb+ processes can be extended to cover WebSockets. There is one caveat in terms of username/password authentication which we will discuss below. A full discussion on kdb+ permissioning is beyond the scope of this whitepaper; instead, please refer to the [July 2013 whitepaper](#)<sup>10</sup>.

### Username and password

Client authentication is not defined in the WebSocket protocol, and in most cases, it is up to the developer to implement an authentication method of their choice. This means that being prompted for a username and password by the browser when the WebSocket makes a request cannot be guaranteed across all browsers, Chrome and Firefox do support this, however.

First, create our user/password file and start the server using the `-u` argument.

```
C:\Users\mgrac>type users.txt chris:password
michael:password2
C:\Users\mgrac>q -p 5001 -u users.txt
KDB+ 3.5 2017.11.30 Copyright (C) 1993-2017 Kx Systems
w32/ 4(core 4095MB mgrac desktop-u7p1jte 192.168.1.64 NONEXPIRE
```

```
q).z.ws:{neg[z.w] -8! @[value;-9!x;{'$ "" ,x}]}
```

If we try to connect to the process using Chrome or Firefox, they will prompt for a username and password and, upon correct entry, successfully create the connection. Not all browsers will currently ask for authentication details, and if so their connection attempt will not be successful. When the connection is not successful due to authentication, a response code of 401 (unauthorized) will be returned to the client.

Behind the scenes, Chrome/Firefox are actually sending two requests. When they each receive the first 401 response code, they prompt for a username and password and then send a new WebSocket request with an additional 'Authorization' option in the header.

---

<sup>10</sup> [http://code.kx.com/q/wp/permissions\\_with\\_kdb.pdf](http://code.kx.com/q/wp/permissions_with_kdb.pdf)

As mentioned 'above' , all WebSocket messages will be processed by the `.z.ws` handler. To fully secure a kdb+ system, this handler should be locked down in the same manner as the `.z.pg`, `.z.ps`, `.z.ph` and `.z.pp` handlers.

As of kdb+ 3.4 we can use Secure Sockets Layer (SSL)/Transport Layer Security (TLS) to encrypt connections using OpenSSL. This process will secure any WebSocket server and upgrade its connection protocols to `wss://` and `https://` respectively.

🌐 Cookbook: [Secure sockets stunnel](#)<sup>12</sup>

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12. <http://code.kx.com/q/cookbook/websockets/#secure-sockets-stunnel>

## A simple example – real-time data

This section will present a simple example in which some tables will be updated in the browser in real-time.

The full code can be found in Appendix A along with start-up instructions in order to get the example working. Some of the key features will be explained here. Once the example is successfully running you should be able to see the following tables in your browser continuously updating:

### Select Syms:

VOD.L  MSFT.O  GS.N  BA.N  IBM.N

Filter

### Quotes

sym	time	bid	ask
BA.N	11:57:37	127.82	127.90
GS.N	11:57:37	180.03	180.24
IBM.N	11:57:37	190.82	191.15
MSFT.O	11:57:37	45.04	45.10
VOD.L	11:57:37	338.85	339.37

### Trades

sym	time	price	size
BA.N	11:57:37	127.84	376.00
GS.N	11:57:37	180.14	16.00
IBM.N	11:57:35	190.98	409.00
MSFT.O	11:57:34	45.05	86.00
VOD.L	11:57:36	339.08	705.00

The web page shows the last quote and trade values for each symbol, and gives the user the ability to filter the syms in view

The idea behind the pubsub mechanism here is that a client will make subscriptions to specific functions and provide parameters that they should be executed with. The subscription messages we send to the server will be sent as query strings so our .z.ws message handler is defined to simply evaluate them.

```
q).z.ws:{value x}
```

Next, we initialize the trade and quote tables and upd function to mimic a simple Real-Time Subscriber, along with a further table called subs, which we will use to keep track of subscriptions.

```
// subs table to keep track of current subscriptions
q)subs:2!flip `handle`func`params`curData!"is**"$\:()
```

The `subs` table will store the handle, function name and function parameters for each client. As we only want to send updates to a subscriber when something has changed, we store the current data held by each subscriber so that we can compare against it later.

The functions that can be called and subscribed to by clients through the WebSocket should be defined as necessary. In this example, we have defined a simple function that will return a list of distinct syms that will be used to generate the filter checkboxes on the client and additional functions to display the last record for each sym in both the trade and quote tables. The aforementioned trade and quote table functions will also accept an argument by which to filter the data if it is present.

```
//subscribe to something
sub: `{subs upsert(.z.w;x;enlist y)}
//publish data according to subs table
pub: {
  row:(0!subs)[x];
  (neg row[ `handle]) .j.j (value row[ `func])[row[ `params]]
}
// trigger refresh every 1000ms
.z.ts: {pub each til count subs}
\t 1000
```

The subfunction will handle new subscriptions by upserting the handle, function name and function parameters into the `subs` table. `.z.wc` will handle removing subscriptions from the table whenever a connection is dropped.

The `pub` function is responsible for publishing data to the client. It takes an argument that refers to a row index in the `subs` table and uses it to get the subscriptions function, the parameters to use when calling that function and the handle that it will use in sending the result to the client. Before doing so, it will also use `.j.j` to parse the result into a JSON string. The client can then parse the JSON into a JavaScript object upon arrival as it did in the earlier example. The `pub` function itself will be called on a timer every second for each row in the `subs` table.

One thing that is important to be consider whenever using WebSockets is that the JavaScript `onmessage` function needs a way in which to identify different responses from one another. Each different response could have a different data structure that will need to be handled differently. Perhaps some data should be used in populating charts while other data for updating a table. If an identifier is present, it can be used to ensure each response is handled accordingly. In this example, the responses `func` value acts as our

identifier. We can look at the `func` value and from that determine which function should be called in order to handle the associated data.

```
ws.onmessage = function(e) {
  /*parse message from JSON String into Object*/
  var d = JSON.parse(e.data);
  /*
   * depending on the messages func value,
   * pass the result to the appropriate handler function
   */
  switch(d.func){
    case 'getSyms' : setSyms(d.result); break;
    case 'getQuotes' : setQuotes(d.result); break;
    case 'getTrades' : setTrades(d.result);
  }
};
```

The rest of the JavaScript code for the client has been seen in previous examples. The tables that update in the browser are simply being redrawn every time the client receives a new response for the appropriate table.

The end result is a simplistic, interactive, real-time web application showing the latest trade and quote data for a range of symbols. Its intention is to help readers understand the basic concepts of kdb+ and WebSocket integration.

## Conclusion

This whitepaper has shown how WebSockets can be used as part of a HTML5 GUI to connect to a q process and allow persistent, real-time communication between kdb+ and a web browser.

There are different methods for sending messages over the connection, and we have seen how to parse kdb+ data into JSON objects using both server-side and client-side methods. Both of these methods have their benefits and drawbacks so it is important to consider the application infrastructure when deciding which method will be most suitable. Serialising data across the connection is easy to achieve using the `-8!` and `-9!` functions on the kdb+ server and the `c.js` code provided by Kx on the JavaScript client. Alternatively, the kdb+ `.j.j` and `.j.k` functions can be used in conjunction with a browser's native JSON parser to achieve the same result.

*Dashboards for Kx* provide a range of great ways to visualize and analyze both real-time streaming data and highly-optimized polled queries on intra-day and historical data. Completely configurable, *Dashboards for Kx* enable clients to quickly build powerful grids and charts of the underlying data stored within Kx and other databases.

 [Dashboards for Kx](#)<sup>13</sup>

All tests were run using kdb+ version 3.5 (2017.11.30)

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13. <http://kx.com/media/2016/07/Dashboards-for-Kx-Product-Overview.pdf>

# Appendices

The following code is also available on GitHub at [kxcontrib/websocket](https://github.com/kxcontrib/websocket)<sup>14</sup>.

---

14. <https://github.com/kxcontrib/websocket>

## **A. SimpleDemo.html**

```

<!doctype html>
<html>
<head>
  <title>WebSocket Demo</title>
  <style>
    /* define some CSS styling on page elements */
    #txtInput {width: 85%; height: 60px; float:left; padding: 10px;}
    #cmdInput {margin-left: 10px; width:10%; height:80px; font-weight: bold;}
    #txtOutput {
      width: 96%; height: 300px; font-family: "Courier New"; padding: 10px;
      border: 1px solid gray; margin-top: 10px; overflow:auto;
    }
  </style>
</head>
<body>
  <textarea id="txtInput" placeholder="q"></textarea>
  <button id="cmdInput" onclick="send();">Go</button>
  <div id="txtOutput"></div>
</body>
<script>
  var ws, cmd = "";
  var input=document.getElementById("txtInput");
  var output=document.getElementById("txtOutput");
  function connect(){
    if ("WebSocket" in window) {
      ws = new WebSocket("ws://localhost:5001/");
      output.value="connecting...";
      ws.onopen=function(e){output.innerHTML="connected"};
      ws.onclose=function(e){output.innerHTML="disconnected"};
      ws.onerror=function(e){output.value=e.data};
      /*
        when a message is received,
        prepend the message to the display area
        along with the input command
      */
      ws.onmessage=function(e){
        /*
          the message is in plain text, so we need to convert
          ' ' to '&nbsp;' and '\n' to '<br />' in order to display
          spaces and newlines correctly within the HTML markup
        */
        var formattedResponse = e.data.replace(/ /g, '&nbsp;')
          .replace(/\n/g, '<br />');
        output.innerHTML = cmd + formattedResponse + output.innerHTML;
        cmd="";
      }
    } else alert("WebSockets not supported on your browser.");
  }
  function send(){
    /*
      store the input command so that we can access it later
      to print in with the response
    */
  }

```

```
    */
    cmd = "q)" + input.value + "<br />";
    /* send the input command across the WebSocket connection */
    ws.send(input.value);
    /*
       reset the input test box to empty, and
       focus the cursor back on it ready for the next input
    */
    input.value="";
    input.focus();
}
connect(); //call the connect function
</script>
</html>
```

## B. Publish and subscribe

Below are four separate scripts which can be copied into a text editor and saved with the respective names in the same directory. Start the q processes up first, and then open the HTML file in a web browser.

### B.1 pubsub.q

Start this process first. It will create the q interface for the WebSocket connections and contains a simple pubsub mechanism to push data to clients when there are updates.

```

\p 5001
.z.ws:{value x};
.z.wc: {delete from `subs where handle=x};

/* table definitions */
trade:flip `time`sym`price`size!"nsfi"$\:(());
quote:flip `time`sym`bid`ask!"nsff"$\:(());
upd:insert;

/* subs table to keep track of current subscriptions */
subs:2!flip `handle`func`params!"is*$\:(());

/* functions to be called through WebSocket */
loadPage:{ getSyms[.z.w]; sub[`getQuotes;enlist `]; sub[`getTrades;enlist `]};
filterSyms:{ sub[`getQuotes;x];sub[`getTrades;x]};

getSyms:{ (neg[x]) .j.j `func`result!(`getSyms;distinct (quote`sym),trade`sym)};

getQuotes:{
  filter:$(all raze null x;distinct quote`sym;raze x);
  res: 0!select last bid,last ask by sym,last time from quote where sym in filter;
  `func`result!(`getQuotes;res)};

getTrades:{
  filter:$(all raze null x;distinct trade`sym;raze x);
  res: 0!select last price,last size by sym,last time from trade where sym in filter;
  `func`result!(`getTrades;res)};

/*subscribe to something */
sub: `{subs upsert(.z.w;x;enlist y)};

/*publish data according to subs table */
pub:{
  row:(0!subs)[x];
  (neg row[`handle]) .j.j (value row[`func])[row[`params]]
};

/* trigger refresh every 100ms */
.z.ts:{pub each til count subs};
\t 1000

```

## B.2 fh.q

This will generate dummy trade and quote data and push it to the pubsub process. The script can be edited to change the number of symbols and frequency of updates.

```

/* q fh.q */
h:neg hopen `:localhost:5001; /* connect to rdb */
syms:`MSFT.O`IBM.N`GS.N`BA.N`VOD.L; /* stocks */
prices:syms!45.15 191.10 178.50 128.04 341.30 ; /* starting prices */
n:2; /* number of rows per update */
flag:1; /* generate 10% of updates for trade and 90% for quote */
getmovement:{[s] rand[0.001]*prices[s]}; /* get a random price movement */

/* generate trade price */
getprice:{[s] prices[s]+:rand[1 -1]*getmovement[s]; prices[s]};
getbid:{[s] prices[s]-getmovement[s]}; /* generate bid price */
getask:{[s] prices[s]+getmovement[s]}; /* generate ask price */

/* timer function */
.z.ts:{
  s:n?syms;
  $[0<flag mod 10;
  h(`upd;`quote;(n#.z.N;s;getbid'[s];getask'[s]));
  h(`upd;`trade;(n#.z.N;s;getprice'[s];n?1000))
  ];
  flag+:1;
};

/* trigger timer every 100ms */
\t 100

```

This code is from the August 2014 whitepaper [Building Real-time Tick Subscribers](#)<sup>15</sup>.

### B.3 websockets.html

Due to the length of code required for this example, the JavaScript and HTML code have been split into separate files

---

15. [http://code.kx.com/q/wp/building\\_real\\_time\\_tick\\_subscribers.pdf](http://code.kx.com/q/wp/building_real_time_tick_subscribers.pdf)

```

<!doctype html>
<html>
<head>
  <title>WebSocket PubSub Example</title>
</head>
<body onload="connect();">
  <!-- Create a section to filter on syms -->
  <section class="select">
    <h3>Select Syms: </h3>
    <div id="selectSyms"></div>
    <button type="submit" onclick="filterSyms();">Filter</button>
  </section>
  <!-- Set up placeholders to display the trade and quote outputs -->
  <section id="quotes" class="display">
    <div class="split">
      <h3>Quotes</h3>
      <table id="tblQuote"></table>
    </div>
    <div class="split">
      <h3>Trades</h3>
      <table id="tblTrade"></table>
    </div>
  </section>
  <!-- Load JavaScript file -->
  <script src="websockets.js"></script>
  <!-- Define some CSS styling on page elements -->
  <style>
    section {margin:10px;padding:20px;width:95%;}
    button {margin:10px;}
    h3 {margin:5px;}
    table {border-collapse:collapse;text-align:center;width:100%;}
    td,th {border:1px solid black;padding:5px 20px;width:25%}
    .split {float:left;width:45%;margin-right:20px;display:table;}
    #selectSyms {padding:10px;min-height:30px;}
  </style>
</body>
</html>

```

#### B.4 websockets.js

This script will be loaded into the web page by the HTML. Make sure this is saved as a JS file in the same directory as the above HTML file.

```

/* initialise variable */
var ws, syms = document.getElementById("selectSyms"),
    quotes = document.getElementById("tblQuote"),
    trades = document.getElementById("tblTrade");

function connect() {
    if ("WebSocket" in window) {
        ws = new WebSocket("ws://localhost:5001");
        ws.onopen = function(e) {
            /* on successful connection, we want to create an
            initial subscription to load all the data into the page*/
            ws.send("loadPage[]");
        };

        ws.onmessage = function(e) {
            /*parse message from JSON String into Object*/
            var d = JSON.parse(e.data);
            /*depending on the messages func value, pass the result
            to the appropriate handler function*/
            switch(d.func){
                case 'getSyms' : setSyms(d.result); break;
                case 'getQuotes' : setQuotes(d.result); break;
                case 'getTrades' : setTrades(d.result);
            }
        };
        ws.onclose = function(e){ console.log("disconnected");};
        ws.onerror = function(e){ console.log(e.data)};
    } else alert("WebSockets not supported on your browser.");
}

function filterSyms() {
    /* get the values of checkboxes that are ticked and
    convert into an array of strings */
    var t = [], s = syms.children;
    for (var i = 0; i < s.length; i++) {
        if (s[i].checked) {
            t.push(s[i].value);
        }
    };
    t = t.join("");
    /*call the filterSyms function over the WebSocket*/
    ws.send('filterSyms[' + t + ']');
}

function setSyms(data) {
    /* parse an array of strings into checkboxes */
    syms.innerHTML = '';
    for (var i = 0; i < data.length; i++) {
        syms.innerHTML += '<input type="checkbox" name="sym" value="' +
            data[i] + '>' + data[i] + '</input>';
    };
}

```

```
function setQuotes(data) { quotes.innerHTML = generateTableHTML(data) }
function setTrades(data) { trades.innerHTML = generateTableHTML(data) }

function generateTableHTML(data){
  /* we will iterate through the object wrapping it in the HTML table tags */
  var tableHTML = '<table border="1"><tr>';
  for (var x in data[0]) {
    /* loop through the keys to create the table headers */
    tableHTML += '<th>' + x + '</th>';
  }
  tableHTML += '</tr>';
  for (var i = 0; i < data.length; i++) {
    /* loop through the rows, putting tags around each col value */
    tableHTML += '<tr>';
    for (var x in data[0]) {
      /* Instead of pumping out the raw data to the table, let's
      format it according to its type*/
      var cellData;
      if("time" === x)
        cellData = data[i][x].substring(2,10);
      else if("number" == typeof data[i][x])
        cellData = data[i][x].toFixed(2);
      else cellData = data[i][x];
      tableHTML += '<td>' + cellData + '</td>';
    }
    tableHTML += '</tr>';
  }
  tableHTML += '</table>';
  return tableHTML;
}
```